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WHEAT FLOUR AND DIET

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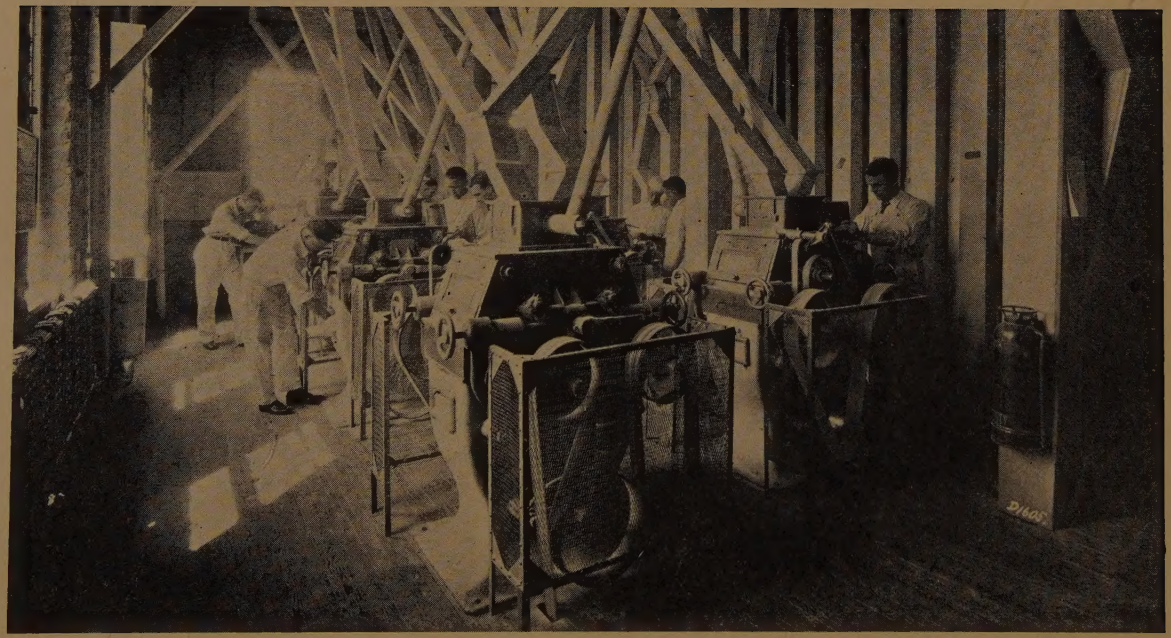

Students in Milling on the Roll Floor of the Flour Mill at the Kansas State Agricultural College
Milling has advanced so far from the crude primitive methods that courses in milling are now offered for credit toward a bachelor's degree.

WHEAT FLOUR AND DIET

BY

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TO MY WIFE

ACKNOWLEDGMENTS

THE author desires to express his appreciation to the following persons of the staff of the Kansas State Agricultural College for reading the manuscript and offering valuable criticisms and suggestions: Martha S. Pittman, Professor of Food Economics and Nutrition; Walter H. Burr, Professor of Sociology; J. S. Hughes, Professor of Chemistry.

Manhattan, Kansas,
February, 1927.

PREFACE

Although wheat flour has been used as a food for man for untold ages, and although at the present time it constitutes one-third of the total food of the people of the United States, there is available comparatively little information on this food material outside of technical publications intended for millers or professional bakers and food experts. In popular writings wheat flour has often been subjected to misrepresentation by certain people who are interested in a particular phase of nutrition. This seems to have given many people wrong ideas about what wheat flour really is, how it is made, what place it should take in the diet, and how its deficiencies should be corrected. Accordingly it appears that there is a need for a book which shall make available to the non-technical reader information on the making of wheat flour and also its place and importance in the diet.

Because wheat flour constitutes such a large part of the diet it is necessary to consider some general aspects of nutrition in order to understand its rational place among the principal foods. This is the reason for devoting considerable space to some of the general relations of food to health and for giving one whole chapter to vitamins. The description of the method of making flour may appear technical

to some readers, but it has been made as simple as seems consistent with a fairly adequate presentation of a complex process. To millers it will appear very elementary, but the object is not to teach milling, but to give the general reader some insight into the different operations involved in making the material for one-third of his food.

While the work of the author has not been primarily in nutrition, he devoted considerable time to research in this field during a number of years while connected with the Department of Chemistry, Kansas State Agricultural College. In discussing nutritional aspects, use has been made of the writings of Dr. E. V. McCollum; Doctors T. B. Osborne and L. B. Mendel; Professor R. A. Dutcher; Professor H. S. Sherman, and Professor J. S. Hughes, as well as others. Historical facts in relation to milling have been gleaned from technical books on milling and from "A Short History of Flour Milling" by H. A. Bellows.

The subject of nutrition is very complex, and in considering the relation of any one food to health it is necessary to remember that life depends not only on food, but on air, sunlight, and sanitation, as well as several other factors. As wheat flour constitutes such a large part of the food material, it is often blamed for nutritional troubles when these are due to entirely different causes.

Considerable of the material in the several chapters bearing on nutrition has been previously published in The Northwestern Miller, The American Miller, and The National Miller.

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WHEAT FLOUR AND DIET

WHEAT FLOUR AND DIET

CHAPTER I

WHEAT FLOUR KNOWN SINCE THE DAWN OF CIVILIZATION

WHEAT flour constitutes one-third of the total energy food of the American people, and of some European nations it constitutes one-half. This at once shows the comparative importance of wheat flour as a food and accounts for adopting such a slogan as "Wheat Will Win the War," during a world crisis. Wheat flour owes its distinctive value to the fact that from it can be made a light bread which has always been universally liked. A given bulk represents a comparatively large amount of food and as it keeps well in storage it can be shipped long distances. To obtain enough bread for all the people has been a constant concern of statesmen, since they know that men hungry for bread do not make good citizens. The lessened per capita consumption of wheat at the present time is a sign of increasing general prosperity.

One of man's earliest methods of making a living was by hunting and fishing. He took what Nature had prepared for him; in other words, he lived by appropriation. This is inferred from the fact that savage people at the present time live in this way and also on the testimony of relics found from primi-

tive people, among which are weapons used in catching game and fish. Primitive man also used leaves, roots, seeds, fruits and other edible parts of plants. By these methods he obtained a variety of food and developed physical strength. This development of physical power, however, was due not only to the nature of the food but also to the fact that conditions of life were so rigorous that the weak perished and only the strongest survived. At the best, existence was precarious. The preponderance of animal food among some races is sometimes given as a reason for physical vigor, but there is one fact in regard to the primitive animal diet that is often forgotten, and which teaches a lesson in nutrition. Primitive man was not as particular as present-day, civilized man in differentiating among the different animal parts, and hence he consumed parts of the animals which are now often not eaten by a large number of people. He more nearly imitated the habits of carnivorous animals and in this way unconsciously obeyed some of the modern laws of nutrition. Civilized man uses for the most part what he calls the "edible portion," the fat and the muscle, and these have been found by modern research to be deficient as the sole nutriment for the human body. Muscle meat is a one-sided or deficient food, the same as flour or several other foods used by civilized man.

People who depended upon hunting and fishing for their main sustenance required a large territory for the support of comparatively few people. This can be illustrated with the example of the American Indian. Before the coming of the white man this country was overpopulated according to the Indians'

way of living and this was one of the reasons why the different tribes constantly waged war on each other. The American Indians were few in number compared with the white men who now live on the western hemisphere. The land which supported a few thousand Indians now supports many more millions. The white men have the same land and the same climate as the Indians had, but they are able to support such a large population because they cultivate the soil and take care of the animals useful to man. Although the Indians had this large territory and used what Nature had prepared for them, their living was more or less precarious, to say the least. The Indians had none of the comforts of life which the white man enjoys. He is able to obtain the comforts of modern civilization because of his more efficient methods, due to his knowledge and mastery of nature's laws. However, it is this very civilization with its methods of living that has brought a large number of nutritional problems. Many of these problems have arisen simply because more and more people must be supported from the same area of land, and food must be transported long distances and stored for considerable periods of time.

Because certain staple articles of food, principally those made from cereals, can be transported long distances and easily stored without deterioration they have always been a chief reliance for food in large population centers. Due to these facts, less of food materials which cannot be transported or stored as easily were formerly used in cities, but, thanks to modern methods of transportation and cold storage, this handicap need not exist to such a large

extent as formerly. It is only in recent times that man has learned how to live in cities in such a way as to maintain or increase the population. In ancient times, the death rate in the cities was always larger than the birth rate and the population was maintained or increased only by influx from the country. It is probably true that improvement in sanitation has been of the greatest importance in safeguarding health in modern cities, but a better understanding of the laws of nutrition has also had a very important influence.

The use of leaves, roots, fruits, as well as seeds, as food for man antedates written history. The need for all of these is just as important as ever. At first man used those plants or parts of plants which he found growing wild and such as were suitable to his needs. Later he learned that certain plants and parts of plants were more pleasing to his palate than others. He also learned that some of these plants which were useful were crowded out by those which were less useful to him. This gave him the idea of protecting those plants which he had found useful, and destroying those for which he had less use. This was the beginning of agriculture.

That certain animals were more useful to man than others was learned a long time ago. It was found that milk from certain animals was valuable as a food not only for adults but particularly for growing children. As in the case of plants, it was discovered that some of the most useful animals were the prey of those that were less useful; hence the primitive man found it was necessary to take care of these useful animals both by providing them

with food and protecting them from other animals less useful. By doing this, man became more sure of his animal food. This was the beginning of animal husbandry.

Thus we see that the tilling of the soil and the keeping of animals are arts that have been practiced since early times. One of the earliest Hebrew records states that Cain tilled the soil and that Abel was a keeper of sheep.

Another lesson learned in ancient times was that in order to have a supply of food in time of need it was necessary to have food either of such a nature that it would keep without spoiling in storage, or to have raw materials which could be prepared in such a way that they would keep. The drying of meat and of fish was one of the earliest arts learned for the preparation of animal food so that it would keep in storage. Cereal grains needed very little preparation for storage and hence they came to be relied upon for food in very early times. The art of preparing food so that it would keep in storage developed earlier with men who lived in more rigorous climates than with those who lived where the climate was milder. However, with the development of the art of food storage began some of the most serious nutrition problems. One of the facts which have been thoroughly well established by modern studies of nutrition is that in order to keep well physically, man must have access to fresh food. If he relies solely upon food which is of such a nature that it keeps well in storage at ordinary temperatures he will encounter serious nutritional problems. This does not mean that foods which keep well in

such storage should be classed as unsuitable. They are good foods and serve a useful purpose, they are absolutely necessary but they must be supplemented by foods that have not been kept long in storage.

The earliest civilization known to written history developed in the valley of the Nile and also in the valleys of the Tigris and Euphrates. In these valleys plant growth was dependent upon irrigation and not upon rainfall. That civilization should develop in an arid country before it developed in a humid country was probably due to the inefficiency of tillage implements available to primitive man. Before man had tools made of iron and steel it was very difficult to subdue land under forest conditions and even under sod conditions. It was easier for him to bring water upon land that grew few or no plants and then cultivate such plants as he desired than to compete with a plant growth already in possession of the soil. Besides, food storage was a simpler problem in an arid than in a humid country.

Because cereal grains had excellent keeping qualities, because a given bulk represented a large amount of food, and because the cereals could be stored in comparatively cheap structures and did not require much preparation for storage, they have been since the earliest times man's chief reliance for food in time of war or famine. An old Hebrew story records that Joseph stored up grain in the years of plenty so as to have a supply in famine years. Tribes which did not have his foresight were compelled to come to him and buy grain. At the present time wheat or wheat flour is a food that can be shipped long distances. It stands transportation well and it keeps

a long time. This is one of the reasons why it has attained a place as one of the world's most important foods.

That the inner part of the grain is more palatable than the outer part has been known a long time. The use of yeast and the art of making bread antedates written history. One of the earliest, as well as the greatest, discoveries in providing palatable food was made when it was found that a dough could be made by mixing yeast and water with the meal obtained from the crushed and sifted wheat, and that this dough would produce a good tasting food when it was heated for a while on a hot stone. When man learned how to make ovens, that is, to place the stones in such a way that the heat was conserved, he could produce a better food. This became known as "bread" and has since early times been one of man's chief articles of diet, especially in those countries where the Aryan civilization developed. Expressions found in ancient literature speak of the value of bread as human food. We find such expressions as these: "Bread of life," "Staff of life," "Man shall not live by bread alone," and "Give us this day our daily bread." These expressions from folklore and sacred literature show the esteem of the people of Egypt, Syria, and Mesopotamia for bread as an article of food.

The dislike for and the difficulties of a one-sided diet is not a new teaching. We read in the Bible that the children of Israel loathed the manna and rebelled because they could not get meat for food. This was not because manna was not a good food but simply that a one-sided diet was unsatisfactory

and insufficient. An old Hindu proverb expresses a similar idea: "A man may live without bread; without buttermilk he dies." This shows that the ancients recognized that bread alone was not sufficient as a complete food and also that milk was recognized as a very good supplement to bread. The desire for something else besides bread and possibly meat is also shown in this ancient expression which signified a very desirable country in which to live: "A land flowing with milk and honey." To "kill the fatted calf" was supposed to be the best that could be done on the most joyous occasions, and to "eat bread at his house" was to have a feast at a friend's dwelling place.

Although wheat has been used so long for human food it is probable that in the earliest times this cereal was too expensive to be used by all the people, and hence was used by only the more well-to-do, and to be able to use wheat as a food became a sign of aristocracy. Wheat has also from early times been a measure of advancing civilization and well-being. Barley appears to be one of the cereals used by the peasantry. Millet and sorghum grains have also been and are staple foods of the poorer classes, especially in some Oriental countries. At the present time the world's most powerful nations use wheat as their principal cereal food.

As soon as man discovered that the inside of wheat was better than the outside he developed tools for crushing and also devices for separating the seed coat from the inside portion. This crude art of milling was probably learned almost as early as the culti-

vation of grain. Old legends relate that the goddess Ceres who taught man the art of agriculture also taught him how to grind the grains. Ancient literature speaks of the excellence of sifted meal. This sifting must have been very crude when compared with the modern sifting of flour from silk bolting cloth. However crude from our modern standpoint, the sifted fine meal or flour as obtained by the ancients was recognized as a food that belonged to the delicatessen class. Homer, the ancient Greek poet, mentions wheaten bread as one of the principal articles of food which was set before the goddess Pallas Athene when she came on a visit to the home of the Greek prince Odysseus, the latter being away but his son Telemachus serving as host. Wheat bread was a food fit to set before a goddess at the home of a prince! The name of Solomon stands in olden times for splendor, wealth, and luxury. Among Solomon's daily provisions are mentioned fine flour and meal. It would be interesting to know the commercial grade of Solomon's flour as judged by present-day standards. People who say that sifting out the bran was introduced by modern milling would have something to learn from history if they would consult the old record. The sifting of the outside of the grain from the inside is an art that antedates Greek and Roman civilization.

Development of the art of milling has been of slow growth, but now modern methods have given the baker of our day and the housewife the finest and the best flour the world has ever known. Furthermore, the flour now delivered into the home

of the poor man is equal in quality to that purchased by the most well-to-do. Solomon's flour or the flour used in making the bread set before the goddess Pallas Athene would be of a very poor grade in comparison, and would not find a ready sale even among the poorest people of the present time.

CHAPTER II

THE COMPARATIVE IMPORTANCE OF WHEAT FLOUR AS A FOOD

WHY has sifted meal from ground wheat, in other words, wheat flour, been relished as a food by man since the beginning of written history or even before? Why such expressions as "Bread is the staff of life" and "Give us this day our daily bread"? There must be some characteristic peculiar to wheat flour which makes it possible to use it in making a food which has a universal appeal. This characteristic is found in the wheat flour protein. This protein is different from that of any other grain. When water is added to flour in the right proportion this protein combines in some way to form a substance known as "gluten" and it is this gluten which makes dough. Dough such as is obtained from wheat flour cannot be made by mixing water with the fine meal of any other cereal. Gluten in dough is intermingled with wheat starch, but can easily be removed by washing some dough in water. It is the yellowish, rubbery, gum-like material which farm boys and girls obtain by chewing wheat. Before modern methods of testing wheat were as highly developed as they are now, millers often tested wheat for quality by chewing a few kernels. Even plant breeders

have successfully used this method in selecting strains of high quality wheat.

Yeast is the leavening agent most universally used in making bread. When this yeast is present in dough and conditions for its growth are suitable the gas, carbon dioxide, is produced. This is the gas which is evolved in the life process of all living organisms. The distinctive character of dough made from wheat flour is that it has power to retain this gas. The production of this gas by yeast growth in the dough changes it to a spongy mass of fine cells. When dough raised in this manner is placed in a hot oven this porous structure is "set" by the heat and there is obtained the light, palatable food known as bread. This bread consists of a mass of small, thin-walled cells, and because of this characteristic it is easily masticated and acted upon by the digestive system. Because of these desirable characteristics of bread people have relished it as a food since ancient times.

The World's Wheat Production

The three great food grains of the world are wheat, rice, and corn or maize. The approximate estimate of the world's wheat production is somewhat over three billion bushels. It is comparatively easy to get estimates on wheat production in western Europe, North and South America, India and Australia. Southeastern Europe is one of the world's large wheat areas, but the amount of wheat produced there is more or less unknown at the present time. Before the World War the production of wheat in

Russia paralleled that of the United States, but since that time comparatively little has been known about the extent of wheat production in Russia. Austria, Hungary and the Balkan states are large producers of wheat and while more is known of wheat production there than in Russia, less accurate information is available than for western Europe and the United States. Wheat is a world crop more distinctly than either corn or rice. A small crop of wheat in North America may mean to workers in European cities a higher price for bread, a large crop may mean a lower price.

The average annual world production of wheat for the years 1921-1925 as estimated by the United States Department of Agriculture is given in Table I, and the average wheat production of the different continents for the years 1920-1925 is given in Table II. The average production in leading wheat-producing countries for the years 1922-1925 is given in Table III, and in Table IV are given the average annual production of leading states of the Union for the years 1923-1925.

TABLE I

AVERAGE WORLD PRODUCTION OF WHEAT

Year	*Bushels*
1921	3,133,000,000
1922	3,184,000,000
1923	3,509,000,000
1924	3,099,000,000
1925	3,349,000,000
Average	3,254,800,000

TABLE II

AVERAGE WHEAT PRODUCTION OF CONTINENTS. 1920-1925.

Continent	*Average (bu.)*
Europe	1,562,000,000
North America	1,172,000,000
Asia	500,000,000
South America	238,000,000
Australia	125,500,000
Africa	97,500,000

TABLE III

AVERAGE WHEAT PRODUCTION OF COUNTRIES. 1922-1925.

Country	*Bushels*
United States	799,243,000
India	356,160,000
Canada	388,233,000
Russia, European	288,261,000
France	282,285,000
Argentina	212,388,000
Italy	199,368,000
Spain	141,738,000
Australia	126,515,000
Russia, Asiatic	104,766,000
Germany	96,447,000
Rumania	92,289,000

TABLE IV

AVERAGE WHEAT PRODUCTION IN LEADING STATES. 1923-1925.

State	*Average Production*
Kansas	106,192,000
North Dakota	105,746,000
Illinois	45,146,000
Montana	44,702,000
Washington	41,478,000
Nebraska	41,352,000

State	*Average Production*
Oklahoma	41,042,000
Ohio	33,406,000
South Dakota	32,004,000
Minnesota	30,119,000
Indiana	29,640,000
Missouri	26,751,000
Idaho	24,072,000
Pennsylvania	21,934,000
Oregon	20,133,000
Colorado	17,441,000
United States	776,457,000

The lowest world production of wheat in recent years was in 1924 and the highest in 1923, the difference being about 400 million bushels, or about one-half of the annual amount produced in the United States.

Europe is the largest wheat-producing continent, followed by North America. Asia, which contains over one-half the population of the world, produces less than half as much wheat as North America, which has about one-fourteenth of the world's population. Most of the wheat in Asia is produced in India. The total produced by the whole continent of either Africa or of Australia is often exceeded by one of the states of Kansas or North Dakota. The bulk of the wheat from South America comes from Argentine. Russia is one of the world's large wheat-producing countries, and outside of Russia, France is the largest wheat producer in Europe.

In the United States, Kansas is the leading state in wheat production, followed by North Dakota. Kansas is the center of the hard winter wheat area,

while North Dakota is the center of the hard spring wheat area in the United States. Most of the wheat from Canada is hard red spring and is similar in quality to that from North Dakota.

The world's production of rice is estimated at about 200,000,000,000 pounds. This approximates in bushels the world's total of wheat. It is more difficult to get accurate estimates on rice production than on wheat production. Countries in which rice is the leading cereal have not developed as accurate crop reporting agencies as have countries where wheat is the leading food cereal. China is one of the large rice-producing countries, and the amount produced there as well as in some other countries is not very accurately known.

While wheat is grown in countries which have climates which can be characterized as moderately dry and which generally have cold winters, rice is the principal cereal crop of hot, moist climates such as prevail in southern China, India, portions of South America, and southern United States. This does not mean that wheat cannot be produced in such climates, but the fight against wheat diseases is such that these countries cannot compete in wheat production with countries which have climates more favorable. Also such countries have climates more suited to rice production. Wheat is the great food cereal of the temperate climates.

The world's production of corn is estimated at a little over four billion bushels and about three-fourths of this is grown in the United States. In contrast with wheat and rice, corn is used more indirectly as a food. It is true that a large number

of people, particularly in southeastern United States, use corn directly as a food, and this may also be said of the people who live in the countries which produce approximately the one billion bushels of corn grown outside of the United States. The bulk of the corn in the United States is used as feed for farm draft animals and in producing beef, pork, dairy and poultry products. It is for this reason that the price of corn in the United States is reflected in the price of almost all food commodities. High-priced corn as a rule means high-priced beef, pork, dairy and poultry products. Any condition, therefore, which brings about high-priced corn will at the same time affect a general increase in the cost of food.

The by-products of wheat, such as bran and shorts, also enter into the indirect production of food. From each bushel of wheat is obtained about 18 pounds of feed, which is used mostly in the production of dairy and poultry products. As the mills of the United States convert annually approximately 600 million bushels of wheat into flour and feed, it means that there are available for this indirect production of food about five million tons of feed. The by-products from wheat are much more valuable than those from rice.

The Calories as a Comparative Measure of Food Values

To get a measure by which to compare the value of different food substances is not as simple as would appear at first thought, since foods serve so many different purposes in human nutrition. The com-

parative money value of foods is too often based on artificial considerations and hence cannot be used in this discussion. One of the best measures for estimating the comparative nutritive value of different foods is the energy or fuel values, since all food substances possess this property to a greater or less degree.

All living beings expend energy for warmth and movement, and this expenditure of energy never stops during life. If the food does not furnish enough fuel material to supply this energy, the body burns its own tissue which means starvation, and if continued results in emaciation of the body and finally death. Therefore a primary requirement of the diet is to furnish enough fuel food to meet the needs of the body. In many recent discussions on food values so much emphasis has been placed on vitamins and the kind of food that sometimes the importance of the proper amount of food, as well as the energy or fuel value, is overlooked by some people. This in a way is a reaction from a condition which existed from twenty to thirty years ago. At that time so much emphasis was placed upon the energy or fuel value that other values were overlooked. At the present time there is danger of the energy value being underemphasized. In the sense that the human body requires fuel material, it may be likened to an engine which converts fuel into power. The human body must also be kept warm as well as have energy for work. For these various reasons energy or fuel values may be used as a measure of the comparative value of a food and as all foods possess this property it is a convenient measure to get

comparisons among foods that are widely different.

Energy values of food are measured in Calories. One Calorie is the amount of heat which is required to raise one kilogram of water one degree Centigrade. The fuel value of coal is usually measured in B. T. U., which means British Thermal Units. Such a unit is equal to the amount of heat necessary to raise one pound of water one degree Fahrenheit. Since one pound equals 453 grams and one degree Fahrenheit equals 10/18 degree Centigrate, one B. T. U. equals .252 Calorie, or in short one B. T. U. is very near ¼ of a Calorie. The fuel or energy requirements for adults is estimated all the way from 2,000 to 8,000 Calories per day, dependent upon body size and work. Most adults who do light physical work require from 2,400 to 3,000 Calories per day, while some men engaged in heavy labor may require as much as 5,000 or more per day. The amount required for children depends upon their age and size. Population statisticians estimate that the number of children under fifteen years of age is equal to about one-fifth of the total population, and some nutrition students estimate that 100 persons of the total population are equivalent to 87 adults. Professor Sherman of Columbia University estimates that the per capita daily Calorie requirement figured for all the people is 2,000 and this figure will be used in some comparisons which are given later.

It is somewhat difficult to get up-to-date and accurate estimates for the per capita consumption of wheat. According to recent figures published by the Bureau of Agricultural Economics, United

States Department of Agriculture, the annual per capita consumption of wheat dropped from 5.4 bushels in 1904 to 4.7 bushels in 1919. The lowest point was reached in 1918, when it was 3.8 bushels. This was due to the efforts of the Food Administration in saving the wheat to help win the World War. At the present time the best estimate seems to be 4.3 bushels annually per person. As this is the per capita consumption, it should be understood that this includes all the children and old people as well. It means that the per capita consumption for adults would be much larger, at least five bushels per capita, and perhaps more.

From 60 pounds, or one bushel, of good wheat are manufactured on the average 42 pounds of flour and 18 pounds of bran and shorts. On this basis the 4.3 bushels of wheat or the per capita consumption would furnish 180 pounds of flour. From this flour would be obtained at 1,610 Calories per pound, a total of 289,000 calories. A per capita requirement of 2,000 Calories per day would equal 730,000 per year. The Calories furnished by the 180 pounds of wheat flour would then equal very nearly 40 per cent of the total required in one year. It will be shown in a subsequent chapter that wheat flour also furnishes from 25 to 30 per cent of the total protein. These facts give a basis for the assertion that wheat flour furnishes one-third of the total food. With people who have to limit food purchases to less expensive food the proportion of bread in the diet is greater than in the diet of those whose incomes permit them to buy more expensive food. Lessened per capita consumption of wheat for the people as a

whole may be taken as a measure of increasing purchasing power.

Decrease in Wheat Consumption

The per capita wheat consumption varies in different countries. The United States Department of Agriculture gives the following figures as the estimate of per capita wheat consumption in the wheat-using countries named:

Per Capita Consumption of Wheat

Country	*Bushels*	*Country*	*Bushels*
Canada	9.5	Netherlands	4.2
Belgium	8.3	Roumania	4.0
France	7.9	Denmark	3.5
Spain	6.1	Chile	3.4
United Kingdom	6.0	Germany	3.2
Switzerland	6.0	Russia	2.7
Australia	5.5	Serbia	2.5
Italy	5.4	Sweden	2.5
United States	5.3	Egypt	2.5
Uruguay	5.3	Portugal	1.8
Argentina	5.2	British India	0.8
Bulgaria	5.0	Mexico	0.8
Austria Hungary	4.3	Japan	0.5

The above figures were compiled from data current a few years ago, but as no more recent figures are available for the different countries they are given here for their comparative rather than their absolute value. In a preceding paragraph it was stated that the annual per capita consumption in the United States was 4.3 bushels, which means that the per capita consumption in the United States has decreased one bushel from the time the above data was compiled. This is corroborated by studies made by the Food Research Institute of Stanford University which have shown that in the last 20

years flour consumption has decreased 20 per cent. If as much wheat was consumed now by the people of the United States as when the above data was compiled, the annual requirement would be over 100,000,000 bushels more wheat than formerly. The place of this wheat has been taken principally by sugar and to a smaller degree by other foods.

In comparison with other countries, the United States occupies an intermediate position in wheat consumption. Canada and several European countries have a much larger wheat consumption than the United States. Some countries like Germany and Russia have a comparatively low consumption of wheat, but they use a large amount of rye. India is one of the large wheat-producing countries of the world and the amount consumed is relatively large in proportion to the amount of wheat produced. India has a large population and produces only about one bushel per capita and about 80 per cent of this total production is consumed by her people. One of the principal grains of India is rice, and this is also true of Japan. In Mexico the principal grain is corn or maize. Less wheat is produced and consumed in the southeastern part of the United States than in any other equal section of this country.

Some investigators in human nutrition think that the consumption of wheat in the United States should not be increased, since greater wheat consumption would entail danger to health and vigor. This thought, however, does not appear to be substantiated by the figures for wheat consumption in Canada, as the health and vigor of the Canadian

soldiers was shown to be equal to that of the soldiers from the United States in the World War, and this may also be said of some other countries where the per capita consumption is larger than in the United States. The per capita consumption of wheat flour in the United States would be greater if the southeastern states were not averaged in with the total, as less wheat is consumed in these states in comparison with the rest of the country. There corn takes the place of wheat with a large number of people, especially among the colored population.

Much has been said and written about the causes for decline in the per capita consumption of wheat flour. A reason very often given is the change from home baking to the use of baker's bread. This no doubt has an influence, but why did people change from home baking to the use of baker's bread? Various reasons have been given, but probably the best reason is the one found in economics. When a family changes from home baking to the use of baker's bread, it is usually a sign that its income has increased. At least it is significant that the increase in the use of baker's bread is coincident with the general rise in the income of workers' families since the World War.

Then there is a lessened demand for fuel foods. People are better clothed, have warmer houses, and the introduction of more automatic machines means that they do less hard physical work. The proportion of "white-collar" workers has increased, and they need less food than those who do heavy manual labor. The increase in labor saving machinery has decreased manual work. There is more machine

tending and office work. When people ride in autos they need less food than when they walk or ride bicycles.

Another reason for decreased flour consumption is that it is in part replaced by more expensive foods such as milk, meats, fats, oils, fresh fruits, fresh vegetables. As great a percentage of this change has come in the last five years as in the fifteen previous years, coinciding with the rise in the average family income. The American family is more prosperous and can buy more expensive foods, hence general prosperity has had considerable to do with decreased flour consumption.

It is significant that the decreased use of flour has been almost paralleled by the increased use of sugar. Statistics show that one hundred years ago, the per capita consumption of sugar was 11 pounds. In 1904 it was 70 pounds, and in 1924-1925 it was 113 pounds. Sugar is a pure carbohydrate, or a pure fuel food. Flour is nearly 74 per cent carbohydrate and to that extent supplies the same need as sugar. In the same period that sugar consumption increased from 70 to 113 or 43 pounds per capita, wheat consumption decreased one bushel per capita. One bushel of wheat will produce on the average 42 pounds of flour and this flour contains 30 pounds of carbohydrate and nearly 5 pounds of protein. Most of the rest is water. The increased use of sugar about balances the decreased use of flour. Besides, sugar is a comparatively cheap food. One pound contains 13 per cent more Calories than one pound of flour. Recently it has been but a little more expensive per pound than flour. It should be

remembered, however, that flour also supplies considerable of the protein.

The total amount of wheat consumed in the United States will gradually increase even if the per capita consumption does not increase, simply because of the increase in population. The following figures give an estimate of the rate at which the population is increasing in the United States.

January 1, 1924	112,826,000
January 1, 1920	105,711,000
Average gain per year	1,778,750
Average gain per year, 1910-1920	1,418,000

This means that the wheat requirement will be from 80 to 90 million bushels more in 10 years than at the present time, and hence there must be produced gradually more and more wheat to meet domestic requirements even if the per capita consumption is not increased.

CHAPTER III

WHEAT FLOUR AND EFFICIENCY IN HUMAN FOOD PRODUCTION

One of the most important measures of the cost of food production is the hours of human labor expended in producing a given amount of food. Measured in this way, wheat production is the most efficient of any enterprise engaged in the production of human food. It takes about the same amount of man labor to produce an acre of wheat as it does to produce an acre of corn, but both require very much less than an acre of rice. But as most corn is used indirectly for the production of human food by first feeding to animals or by feeding to farm draft animals used in the production of food there is as a rule more labor connected with the production of food by this method than by wheat raising, which is used more directly as a food. Seventy per cent of the wheat is obtained as flour, which is used in producing bread and other products. Approximately the same proportions are obtained from corn when this is used in the manufacture of corn meal, starch, sugar or syrup, but when fed to food-producing animals the best returns from corn is about twenty-five per cent in the form of pork and dairy products. This indicates the fundamental reason why more food is obtained with less human effort when used

directly from plants than when plant products are first fed to animals. Under our present system of agriculture food production by means of animal husbandry is just as essential as by means of grain production, but as more people can be supported on a given area of land when most of the food comes directly from plants it means that, as population increases, the proportion of animal food direct from plants must be increased. Thus in such countries as China and Japan very little animal food is available, while on some of the Asiatic steppes most of the food is in the form of meat and milk.

When any plant product is first fed to animals only about 10 to 25 per cent of the energy value is returned in the form of human food. The animal uses the larger part of the food eaten for its own body requirements and only what is consumed over and above this is returned as material which can be used as human food. There is a great difference in different farm animals in their efficiency of conversion. Dairy cows are probably the most efficient producers of human food, and next to them may be placed poultry and swine, and last beef cattle. The latter, however, consume the coarse parts of the plants and for this reason they are essential in the economy of human food production. This is particularly true of newer countries having an extensive range. With the growth of population more efficient methods of food production must be used. This means not only that more and more food must be obtained directly from plant sources but also that a larger proportion of the more efficient animals must be used as food producers, such as dairy cattle,

swine, and poultry. Because of this economic situation wheat will continue to be one of the largest sources of food for the white race.

More food is produced per hour of human labor in the United States at the present time than ever before in the world's history. The introduction of labor-saving machinery on farms has had more to do with the lessening of the cost of food as measured by hours of human labor than any other factor. This is due to the simple fact that it has multiplied several times the amount produced per man. The invention and introduction of automatic machines in manufacturing processes have been the cause of the greatest industrial revolution the world has ever witnessed. To this, more than to any other cause, may be traced the great increase in material wealth. What were considered luxuries a generation ago are now necessities for the average family. A generation ago only the well-to-do families in town could afford a carriage with solid rubber tires and ball-bearings. Now the man with an automotive inclosed carriage, pneumatic rubber tires and roller-bearings is not one in a thousand but one like a million others. The automatic machines have made most of our present-day industries possible. Without such machines the automobile would be a luxury instead of a necessity. While the introduction of labor-saving machinery in the production of raw materials used for food production may not be as spectacular as in the industries, yet as measured by human labor, food is cheaper to-day than it has ever been before, due simply to the fact that the ultimate cost of any basic necessity such as food is not

measured so much by artificial means such as money but in terms of human labor.

The greatest example in the world's history of man's power to conquer land and produce an abundance of food is the settlement of the prairies of the Mississippi and Missouri valleys. With modern steel implements this land was easily prepared for the production of cereal grains. Coincident with the breaking up of these prairies took place the greatest development of agricultural machinery in the world's history. This resulted in such an abundance of food that the like of it has never been known before or since. This phenomenon can never happen again, as far as it is apparent to any observer at the present time. There are no such vast stretches of fertile land awaiting man's conquest, and we cannot expect such a tremendous development in agricultural machinery as can be seen by comparing the Daniel Webster plow with the present large gang-plows which not only plow but prepare the soil and sow the seed as well; also by comparing the old-time cradle with the present harvester, not to mention the combine harvester and the thresher.

The use of automatic machinery in connection with flour milling was introduced in the latter part of the eighteenth century. This means that the milling industry was one of the first, if not the first, great industry to use the automatic principle. The automatic mill such as we know it at the present time was developed in America while millstones were still used as grinders. The value of the automatic principle, however, was very quickly learned and now these mills are found not only in Europe

but all over the world. The automatic wheat flour mill of the present day may be said to be the greatest labor-saving device ever used in the preparation of food for human consumption. Data will be presented which show that in efficient mills each man's labor of eight hours produces from 20 to 40 barrels of flour; in other words, eight hours of one man's labor will mill as much flour as 20 to 40 adults consume in one year.

While it takes very much more labor to produce the wheat on the farm than to grind it into flour at the mill, yet wheat production as measured by human labor is very efficient. Careful agricultural surveys have established that on the average, under fairly efficient methods of wheat production, each bushel of wheat represents 30 minutes of man labor. One basis for this assertion is the following set of figures taken from the director's report, 1922-1924, of the Kansas Agricultural Experiment Station. The investigation was made in McPherson County, Kansas, and the figures are the averages obtained from a survey of 21 farms and they can therefore be considered representative of what may be obtained under modern conditions on farms in the great wheat belt. The figures represent hours of man labor per acre of land in wheat.

Year	*Hours prior to harvest*	*Hours to harvest*	*Total hours per acre*
1921	3.52	3.08	6.60
1922	2.70	4.06	6.76
1923	3.25	3.06	6.31

As the average wheat production in the United States is around 13 or 14 bushels per acre, it follows

that each bushel represents very nearly one-half hour of man labor. The above figures were obtained in connection with wheat production where harvesters were used. Where headers are used it is more efficient, and still more efficient where combine harvesters and threshers are used.

In a preceding chapter it was pointed out that the average wheat consumption for adults in the United States is about five bushels and it was also shown that this represents the raw material for one-third of the total energy food. This means that 2.5 hours of man labor efficiently spent in wheat raising produces one-third of the raw materials for the total energy food consumed by an average adult person per year. In other words, if all raw materials for food could be produced as efficiently as wheat, 7.5 hours of man labor would produce this raw material required for one adult in one year. But since the saying "Man shall not live by bread alone" is true physically as well as spiritually, there is another story to the production of raw materials needed for human food.

It has already been intimated that the milling of flour is conducted with even greater efficiency than the production of wheat. In ancient times the grinding of grain was one of the most irksome tasks. In Rome this was the labor of slaves, and after Constantine abolished slavery, milling was largely done by prisoners. Because of the abundance of military slaves the government of Rome became the great ancient miller. Milling was considered degrading work, work that a gentleman should not do. If a man did not have slaves he made his wife or

wives do the milling. At the present time flour is so common and so cheap that the miller, like sunshine, is taken for granted. No other machine in modern times engaged in the production of materials which minister to human needs compares with the flour mill when measured by labor requirements in relation to output. As the modern flour mill produces from 20 to 40 barrels each day of man labor applied, it means that it requires from 12 to 24 minutes of man labor to mill all the flour the average adult person eats in one year. This represents only the work at the mill and does not include the work required to bring the wheat to the mill and to transport the flour in a cloth sack to the consumer.

Civilization, as we know it, is possible because man has invented contrivances which enable him to have a surplus of time and energy left after he has provided for the bare necessities of life. The greater this surplus the greater the civilization possible. When most of man's time was consumed in providing food and shelter there was little opportunity to pursue art and education and provide for the comforts of life which are now enjoyed by the average person. Among the various agencies which have contributed to make this civilization possible the flour mill may be assigned a very prominent place.

Not only has there been a tremendous saving in human labor required to produce flour but the quality has also been immeasurably improved. In ancient times although produced by very crude methods, finely ground and sifted flour was a part of the offerings to the gods and was a food fit to entertain angels unawares. Fine flour is mentioned as

one of the luxuries of Babylon, a city which stood for wealth and indulgence. These statements found in old literature in regard to flour show something of the esteem the ancients had for this food, but their flour would be very poor indeed when judged by modern standards. This means that the modern flour available to any one at the present time is a food of very superior quality.

CHAPTER IV

WHEATS USED IN MAKING FLOUR

THE first essential in making good quality flour is to have good quality wheat. To many people wheat is simply wheat; to millers and grain men there are all kinds and conditions of wheat. To many people flour is only flour; to the housewife and to the baker there are many kinds of flour. Flour is used for a variety of purposes and one flour is better suited for one purpose than is another flour. Sometimes a flour may be judged "poor" when the trouble is simply that the flour is not suited for the particular purpose for which it is used. For a different purpose it might be excellent. Since the quality and character of a flour depend primarily upon the quality and character of the wheat it is necessary to select the right kind of wheat and then mill it according to such methods as are necessary to produce the required quality of flour. For this reason the selection of wheat is a very important part in the production of flour. Unless the miller is successful in this he will not be successful in producing the quality of flour required by his trade.

The wheats of the United States may be divided into two main groups: the hard and the soft wheats. Under each of these are several subdivisions. The hard wheats, except Durum, are the preëminent

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bread wheats. They are particularly suited for making the flour used in making bread with yeast as the leavening agent. Such flours are in great demand by the commercial baker. He prefers such flours because they produce a comparatively large amount of light bread from a given quantity of flour and they are also best adapted to the conditions which prevail in the commercial bakeshop. The more bread that can be made from a given quantity of flour the greater the profits. In the commercial bakeship most of the work is done by machinery and the baking operations must proceed according to a certain order or sequence. If anything happens to this sequence, then an undue strain is put on the flour. For this reason the commercial baker wants a flour which has reserve strength, one that can stand punishment, and this he finds particularly in the hard wheat flours.

The soft wheats are better than the hard wheats for making flour used in all kinds of pastry baking, cracker baking, and for making self-rising flour. In short, these flours are better suited for baking when soda or baking powder is used as the leavening agent. This does not mean that light bread cannot be made from flours made from soft wheat, with the use of yeast, nor that hard wheat flour cannot be used for baking when the leavening is produced in other ways than by yeast. It simply means that one kind of flour lends itself better to one purpose than another. The reason for this is found in the quality of the gluten. The hard wheat flours yield a gluten which is characterized by that quality designated by the word "strength." It means that such flour has

a large absorption; that is, in baking, more water is used and this results in more bread as well as in bread that is lighter and more palatable, the very qualities that are demanded by the consumer. The quality of gluten in soft wheat flours is as a rule more pliable; that is, it stretches more easily and hence when used in pastry baking there is obtained that light, porous structure which is particularly desired in cakes. Soft wheat flour is also very well adapted for use in cracker baking.

The hard wheats are divided into two general divisions or classes; those produced from fall-sown varieties and those produced from spring-sown varieties. The leading hard winter wheat state is Kansas, with Nebraska and Oklahoma following. Considerable quantities are also produced in other western states. No hard wheat is produced in the eastern states. The leading hard spring wheat state is North Dakota, with South Dakota and Montana following. The wheat of western Canada is mostly hard spring wheat. Hence the plains area of the United States, beginning with northern Texas and continuing into western Canada, is the greatest single area of the world for the production of the wheat which is preëminently suited for making light bread.

There are a number of different varieties of hard winter wheat, such as Turkey, Kanred, and Kharkof, as well as others. There are also several varieties of hard spring wheat; the leading hard spring wheat variety is Marquis and other varieties are known as Preston, Kota and Red Fife, and Prelude. About 25 per cent of the total wheat area of the United States is sown to hard spring wheat, and about 32 per cent

WHEAT HEADS

Wheat heads of two well-known hard winter wheat varieties; Turkey and Kanred.

is sown to hard winter wheat. Thus it follows that considerably more than one-half the wheats of the United States are particularly suited for making bread flour.

There is no essential difference in the flour made from hard winter or hard spring wheat as classes if the quality of the individual wheat is the same in both cases. There is considerable variation within each class. Some hard winter wheats are better than some hard spring wheats, and some hard spring wheats are better than some hard winter wheats. In some years the hard spring wheats as a whole are of a higher quality than the hard winter wheats as a whole, and in other years the reverse is true. There is also considerable variation within each class due to local conditions. Every wheat buyer knows that the quality in some sections in the same wheat area is different from the quality in another section.

There are several kinds of soft wheat, but the leading class of soft wheat is known as "soft red winter." About 30 per cent of the total wheat area of the United States is sown to this class of wheat. The leading states are Missouri, Illinois, Indiana, Ohio, Pennsylvania, with smaller amounts grown in other states. There are more varieties within this class of wheat than in any other class. This was the wheat mostly grown in the United States until the hard winter wheats of the Southwest and the hard spring wheats of the Northwest were introduced and developed. Therefore, the soft wheats are the ones that figure in the early history of the United States.

The wheats that have been mentioned, hard red

winter, hard red spring and soft red winter, comprise from 85 to 90 per cent of all the wheat grown in the United States. The remainder of the wheats are mainly white wheats and Durum. There is another wheat known as "club wheat" but the area occupied by this is very small and it is relatively unimportant from the standpoint of total wheat. Durum is a hard wheat but is not classed as a bread wheat. This does not mean that bread cannot be made from Durum wheat flour; it simply means that the quality of the other hard wheat flours is so much better for bread making than Durum wheat flour that it is not desired for this purpose; however, a small amount of Durum wheat flour is blended with other flour in bread making. The flour from Durum wheat is often known as "Semolina" because of its granular character. This flour is best adapted for the manufacture of macaroni, spaghetti, and similar products, and about 20 million bushels of Durum wheat are used annually for this purpose.

Durum wheat is a spring wheat. It is rust resistant and drought resistant, and most of it is grown in North Dakota and Montana. It is because of its drought-and-rust resistance that it is preferred by farmers in some places to other hard spring wheats.

Some varieties of white wheats are hard, others are soft; some are spring-sown and some are fall-sown. The white wheats are grown mostly in the Pacific Northwest, in some of the mountain states, and also in western New York. Most of the white wheats are used for the manufacture of breakfast foods, for making pastry flour, and for flour used in baking crackers.

Factors That Determine Quality in Wheat

While there are many factors which determine quality in wheat they may all be placed under three headings: climate, variety, and soil. This presupposes that conditions of harvesting and storage are such as to preserve whatever good quality is in the wheat after it has matured in the field. Climate is a composite of various factors, among which are temperature, amount of rainfall, average relative humidity, wind velocity and rate of evaporation. Because of the composite character of climate it is very difficult to determine which one of the individual factors is most effective for any particular crop.

The hard winter and the hard spring wheats are grown in a climate which may be characterized as "continental." Such a climate has from moderate to severe winters but relatively hot and dry summers. The best quality of these wheats is grown where the average rainfall is 30 inches or somewhat less. In considering the effect of rainfall on wheat production not only the total annual rainfall must be considered but also the distribution. A suitable distribution of 15 inches may result in a better crop than an unfavorable distribution of 30 inches. As the fall-sown varieties are dependent for successful growth on the character of the winters, the cultivation of these wheats is not practiced extensively north of central Nebraska. The spring-sown varieties do not depend on the character of the winters, but their limit of growth depends upon the length of the summer, and hence they are grown as far north as they can be matured before a killing frost.

The fall-sown varieties, as a rule, produce more bushels per acre than the spring-sown varieties, and hence the former are cultivated as far north as they will endure the winters. Plant breeders are all the time endeavoring to secure varieties which are resistant to cold. With the success of their efforts fall-sown varieties may be grown further and further north.

The soft red winter wheats are grown where the climate is characterized by greater humidity and larger rainfall than where hard winter wheat is grown. The soft red winter wheats are less drought resistant than the hard wheats, both spring and winter, and while they are not able to withstand as severe winters as the hard red winter wheats they can withstand greater amounts of moisture during the growing season. They have a stiffer straw and are less subject to lodging, hence they are adapted for growing on very productive soils. They produce the best results where the rainfall is above 30 inches or considerably more per year.

While in a general way climate seems to be the most potent influence in determining the quality of wheat, soil and individual varieties are also determining factors. It was the introduction of hard Turkey wheat from Russia that started Kansas and adjoining states as wheat growers on a large scale. Before the introduction of this wheat Kansas grew the soft red winter wheat varieties and also spring wheat. Now the soft winter wheat is limited mostly to the eastern part of the state, and the amount of spring wheat grown is negligible. Turkey wheat had been grown in Russia under climatic conditions

very similar to those which prevail in the Kansas wheat belt, and hence when this wheat was sown in Kansas it found itself in an environment to which it was accustomed and for this reason this wheat was a success from the start.

Varietal characteristics are more fixed in certain wheats than in others. Certain white wheats are always soft; while other wheats tend to remain hard even in localities where other wheats tend to become soft. Casual observations, as well as careful study, have shown that varieties are to a large extent influenced by environmental factors. The same variety of Turkey wheat grown in the eastern one-third of Kansas will not have the same quality as that grown in the western one-third, even if both were grown from the same seed in the same year. It would be theoretically possible to start with almost any good variety of wheat of a particular class, such as hard red winter or hard red spring, grow it in a certain place, and then by breeding and selection for many years develop a variety that would be adapted to those local climatic and soil conditions in which the wheat was grown. This is not a practical method. The successful wheat breeder chooses as foundation stock those varieties which are best suited to his environmental conditions. If he works in a territory where soft wheat produces the best results then he endeavors to develop strains of soft wheat suitable to prevailing conditions. If he lives in a territory where hard red spring or hard red winter wheats are best, then he tries to develop good strains of these wheats. Hard winter wheat would be a failure in North Dakota, and hard red spring wheat would not

be profitable in Kansas, nor would a hard red winter wheat retain its typical characteristics in the eastern states.

Just how far certain characteristics in a variety are inherited is difficult to say. That some characteristics are inherited to a degree is certain. If this were not true the plant breeders could not be successful in developing better varieties. However, since both soil and climate influence characteristics in the wheat, it is necessary to be on guard at all times so as not to mistake characteristics which are due to soil and climate for those which are due to the variety.

Climate and variety have been emphasized so much that the importance of the soil factor is sometimes overlooked. The more the soil factors are studied the more it is realized that climate and variety influence the wheat through the medium of the soil. Wheat is grown on many kinds and types of soil. Soils may be classified on the basis of physical texture, which in turn is determined by the relative amount of sand and clay. Soils may also be classified on the basis of their content of plant nutrients. Some soils have an abundance of these nutrients and in others these nutrients are relatively scanty. These factors affect the character and quality of the wheat. Because soils vary from one field to another and from place to place, it follows that there will be a considerable variation in wheat due to the soil factors.

The soil is the home of the wheat plant during the period of growth and development. It is through the soil that the wheat receives its water and other

plant nutrients. It is not only necessary that water shall be supplied through rain or irrigation but the movement of the water through the soil must be such that the wheat is well supplied, particularly in critical periods. Water moves through different soils at varying rates and for this reason the same variety grown in the same climate may give wheat of different quality because grown on different kinds of soil. Plant nutrients, particularly nitrogen and certain inorganic elements, must not only be present in the soil but they must also be in a condition available for the use of the plant. These nutrients are made available by suitable methods of soil management and hence it is possible for the farmer by different methods of soil culture to influence the quality of the wheat. Any wheat buyer in a country elevator knows that wheats from different parts of his territory are not the same in quality. This may be due to the fact that certain areas have more sandy, light soils, while others have more heavy soils. In fact, different fields on the same farm will produce different qualities of wheat due to the varying soil factors, such as texture and availability of plant nutrients. Wheat grown on recently broken prairie soils has a quality which is superior to that of wheat grown on old, worn soils, and hence wheats from newly settled countries which have good soils have been famed for their excellent quality. This is one reason why the wheats from western Canada at the present time have such a good reputation.

These factors which influence quality of wheat, such as climate, variety, and soil, may be called the pre-harvest factors. They are all-important because

after the wheat is produced there is very little that can be done to improve the quality; however, much may be done to injure it, and hence it is necessary that the qualities which Nature has put in the wheat be preserved. It is easily possible that after a good quality wheat has been grown it may be seriously damaged by conditions which prevail at the time of harvest and also by conditions of subsequent storage. Wheat cut in the early ripening period will not have the same quality as wheat cut when dead ripe. Wheat harvested during a rainy and wet period will not have as good quality as that harvested under good weather conditions. This does not mean that a good quality wheat may not be obtained under somewhat adverse harvesting conditions if due care is exercised, but the danger of spoiling during unfavorable weather is so great that unless great care is taken the quality of the wheat will be greatly impaired.

The amount of moisture in wheat is the most important factor which affects its quality during storage. Ripening is in part a process of desiccation. If wheat is not sufficiently ripened it contains too much moisture and if stored with this amount of moisture the quality will be seriously impaired. The wheat kernel may be said to be a miniature wheat plant under dormant conditions. Ripening is a process of preparing for this condition of dormancy. The dormant condition of wheat is one in which these vital activities are slowed down to the lowest possible limit, but the vital activities may be increased by the presence of a certain amount of moisture. If wheat is cut before it is ripe the vital

activities are still too vigorous for the wheat to be put into storage, also if too much moisture is added to wheat by rain and then if it is stored too damp the quality is injured because the presence of this moisture starts those vital activities which are associated with germination of wheat. The prevailing temperature is also important. In warm weather the danger of damage from a certain amount of moisture is much greater than in cold weather. Unsuitable conditions of storage may injure wheat so seriously that the flour will be unfit for use.

The quality of wheat may also be impaired by wheat diseases such as smut and rust. These diseases interfere with the vital activities going on in the wheat plant and the kernel is robbed of some of its constituents essential to quality. The amount of injury to wheat from smut or rust varies from very little to as much as to make the wheat unfit for milling. Rust has a tendency to produce low yields of shriveled wheat. Such wheat gives in milling a small amount of flour of poor quality. Smut, particularly the stinking smut, also decreases acre yield and the wheat which is produced has such an offensive odor that it cannot be used for milling before it has been washed, and the flour has lost much of its quality and strength.

Measures of Quality in Wheat

Important measures of quality in wheat are weight per bushel or test weight; color or appearance; and protein content. The two former have been used for a long time in estimating the quality of wheat, but of late years protein has also assumed

a place of importance, especially in measuring the quality of hard wheats. Weight per bushel or test weight is a measure of quality because, other things being equal, the higher the test weight the more flour will be obtained from a given amount of wheat. For instance, 100 pounds of wheat whose test weight is 58 will produce 71 pounds of flour and 29 pounds of feed, while 100 pounds of wheat whose test weight is 60 will produce 72 pounds of flour and 28 pounds of feed. Since flour sells, pound for pound, for about three times as much as feed, it follows that a wheat which will produce more flour is worth more to the miller and for this reason test weight is one of the most convenient, as well as valuable, means of measuring quality. This method of measuring quality is used at every country elevator, and whenever a farmer brings in a load of wheat the buyer determines the test weight by a convenient instrument and this helps to establish the grade of wheat and the price.

Color is a measure of quality, as this indicates soundness and the general effect of harvesting and storage conditions. A clear, bright color characteristic of the particular variety of wheat represented indicates that the inherent qualities produced while the wheat was growing have been preserved. A bleached or dull color indicates that the wheat has suffered injury from unfavorable harvest conditions. These conditions may have gone to the extent of starting germination. The amount of injury may vary from very little to as much as to make the wheat unfit for milling. If wheat has heated in the stack or during storage in the bin this will be shown

by a darkened color of the bran coat. Such injury is usually more serious than the injury which may take place during unfavorable harvesting conditions.

Protein is valuable as a measure of quality particularly in hard red wheats because the per cent of protein is very closely related to those qualities the commercial baker wants in a bread flour. Other things being equal, the higher the per cent of protein the greater the yield of bread from a given amount of flour. It is also usually true that in a hard wheat the higher the per cent of protein the greater is the stability or margin of safety in the flour against unfavorable baking conditions. In other words, from such a wheat will be produced a flour which will make good bread even if the baking conditions are not ideal. While the above is generally true in regard to per cent of protein, there are some very important exceptions. It is very possible to have several wheats of similar protein content which will produce flours which differ greatly in baking qualities. The reason for this is that the quality of protein is just as important as the quantity. For instance, if the wheat has been injured during harvesting and storage the quantity of protein may not be affected but the quality has been seriously impaired. It is also true that the quality of protein varies in different varieties of wheat grown on the same soil and under the same climatic conditions. This is due to the inherent qualities in the individual varieties or strains. Some varieties have protein of much better quality than others. It is also true that the quality of protein may be affected by soil and other growth conditions. As a rule the

best growth conditions produce the best quality of wheat protein from any given variety.

The above is a brief statement of the factors which affect quality in wheat. Much more could be said, but enough has been indicated to show that wheat is not simply wheat but that there are many kinds and differences. Wheat is grown under a number of kinds of conditions, and varieties are used which are suitable for several different purposes. Many factors affect the plant while it is growing, and the quality of the wheat may also be affected by a number of factors which obtain during harvest and storage. In these various ways the qualities of the wheat as determined by conditions on the farm, in the warehouses, and in the mill, are reflected in the qualities of the flour which comes to the consumer.

CHAPTER V

THE DEVELOPMENT OF MILLING

The grinding of grain, which is now one of the major manufacturing industries of the world, can be said to have had a longer continuous existence than any other industry. It traces back to the time before written history began. The grinding of grain or the production of flour was formerly one of the industries like spinning and weaving which was done in the home. There was a time when the making of flour was one of the household duties the same as the making of other necessities of life. The millstones were among the household articles just as certain crude cooking utensils. Milling, however, was removed from home duties earlier than some of the other home manufacturing processes such as spinning and weaving. These latter were practiced even later than Colonial times, but custom mills had come into existence long before this.

That preparation of flour was a household art even in the best families is known from some of the oldest records. In the Homeric poems, which are supposed to picture a very early Greek civilization, something is shown of the position of milling in connection with the household of a Greek prince. Homer tells us that when Odysseus, after many wanderings, returned to his home he found that his

wife was besieged by many suitors. In the story which tells of Odysseus contemplating what he was going to do to rid himself of these suitors we find this reference to milling: "At the hand mills twelve women in all plied their task, making meal of barley and wheat, the marrow of men. All but one had gone to sleep for they had ground out their task of grain, but one alone rested not yet, being weakest of them all. She now stayed at her quern and spoke a word, a sign to her lord." And this was the way wheat was ground in the household of a prince!

The character of the millstones used may be inferred from a passage in Job, which is thought to be one of the oldest books in the Bible: "His heart is as firm as a stone; yea, as firm as the nether millstone." The importance of the millstone among the Hebrews may be inferred from some of their laws, which state that "No man shall take the mill or the upper millstone to pledge, for he taketh a man's life to pledge." This means that the millstone was indispensable to life, and that it was one of man's rightful belongings. It also means that the millstone was such a valuable possession that in the case of dire need this was an object that could be mortgaged in order to obtain means of subsistence. This law was evidently intended to prohibit people from losing their millstones and so keeping them from becoming public charges.

Milling was hard work and also work that was considered of a low order. It was work that was relegated to slaves. The fact that it was so often the work of women shows us something of the posi-

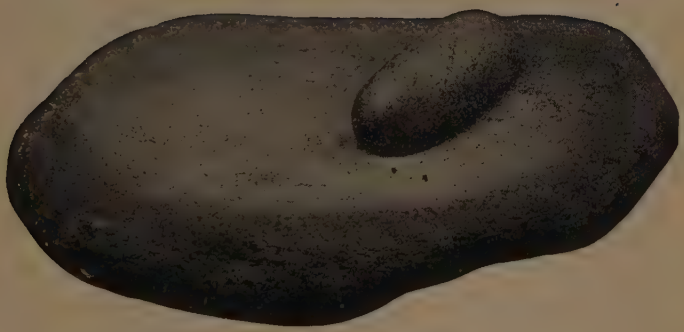
tion of woman in ancient society. When a man had no slaves he made his wife or wives do the grinding. One of the worst threats that could be made against a man was "Thy wife shall grind for another." The work of milling was such that it could be done by persons of rather low intelligence. When the writer of Exodus wanted to picture the two extremes of Egyptian society he put Pharaoh's daughter in the uppermost class, and the maid behind the mill in the lowermost class. Grinding grain was often the work of prisoners. When Samson, one of the Hebrew heroes, but one who acquired a rather doubtful reputation, was captured by the Philistines they first put out his eyes and then they made him grind in prison. His great asset to them was his physical strength, the same as a work animal. Some one with eyes had to superintend the job.

That milling continued to be a household duty even up to the beginning of the Christian era is indicated by one passage in the New Testament which shows that at that time milling was a most common daily task. When the Great Teacher wanted to get an illustration of the importance of being ready at all times, no matter what the occupation, he said, "Two women shall be grinding at the mill." Evidently at that time the making of flour was as much of a daily household task as the baking of bread.

The oldest grinders used by man in crushing grain were his molars. We can picture prehistoric man seated on his haunches beside the fire of his ancient cave home with his wife and children, chewing either the raw or the roasted grain. We can easily under-

stand that the meal was not as pleasant as the one the family now enjoys with the light, flaky bread as one of the foods indispensable at every meal. Chewing grain once or twice as a pastime or as children do in obtaining "wheat gum" may be an easy matter, but when it had to be indulged in for every meal it was rather tiresome. Accordingly, one of the first tools used by man was one for crushing grain. The first principle employed was probably that of impact, or the same as that now used in the mortar and pestle. However, as no iron tools were available, the depression in the nether stone never could be very deep, and the upper stone was probably rather blunt. In doing this work it was noticed that the crushing could be accomplished more easily by rolling and rubbing the upper stone on the nether. This can probably be registered as the first real discovery made in the art of milling. Millstones made to crush grain after this fashion are known as "saddle stones." Such stones have been found in the ruins of ancient Chaldea and probably date back as far as 4000 B.C. The crushing of the wheat by rubbing with pressure used a principle which was employed in milling even up to modern times, and which to a certain degree we use even to-day.

A very interesting observation on how the Cliff Dwellers developed their art of milling may be seen in the ruins in Mesa Verde National Park, Colorado. These people probably lived here from 800 to 1,200 years ago. During the hundreds of years of their tenure, they developed their grinding methods which appear to have been simply an improvement of the



A Stone Mill, Oldest Type

The grain was crushed by rubbing the grain with the smaller stone on the dished surface of the larger flat stone. Such mills were used in ancient Chaldea about 4000-2300 B.C. The above mill was used by the American Indians.

methods of their ancestors or the people who preceded them at Mesa Verde.

The one who visits the ruins to-day, may see a grinding room, where a thousand years ago the girls of the commune made the meal for their bread. The grain was a dent or soft milling variety of red corn. A room may be visited, for example, where there are four stone grinding bins, in a row along the side of the stone wall. Each bin is much like a cement stationary washtub. The front part slants in from top to bottom. The bin is made of sandstone slabs and the slanting slab was roughened by chipping out pieces of stone. The grinding girl placed the grain in the bin, then drew it up over the roughened surface, and rubbed it down with a big smooth stone held in her hands.

The slanting stone in the bin nearest the entrance was more coarsely roughened than the next one, which was somewhat finer, and the third still finer, while the fourth was very much finer. The "roughening" was done by striking them sharply over the surface with a hard flint sandstone. This produced the pits and as the stones wore down these had to be renewed. Probably as the grain was ground in each bin it was thrown over into the other bin where it could be ground again to a greater fineness. The process appears to have been similar in one principle to our modern method of gradual reduction.[1]

As long as the saddle stone was used only one per-

[1] This information concerning the method of grinding by the Cliff Dwellers was supplied the author by Prof. Walter Burr and the Superintendent of the Mesa Verde National Park, Mr. Jesse L. Nusbaum.

son could be employed at each mill. The next step in the invention of tools for milling took place when it was discovered that it was easier to rotate one stone upon another in a semicircle rather than back and forth. This was the invention of the upper and nether millstone. The grain was fed into an opening in the center of the upper stone. The first mills used of this kind were small, generally made for only one person, who rotated the upper stone by means of one or two handles. As hard work is not so irksome when it is done in company with some one else, it became customary for two persons to rotate a larger stone, one person pulling it one way and the other the other way. That this was done we infer from the expression "Two women shall be grinding at the mill'; one woman pulled it halfway around and the other woman pulled it back again. In doing this, the work was probably done with some sort of a rhythmic motion to ease the physical drudgery.

The next step in the advancement of milling was made when the millstone was made to complete a circle. This mill was the quern. Some writers apply the term "quern" also to the mill described in the preceding paragraph. It is probably proper to use this term with all the mills which used the revolving principle whether this was made in a complete circle or back and forth in a semicircle. The revolving principle made possible the use of larger stones, but the use of such stones was not possible until the principle of the lever had been discovered. By the use of the lever and larger stones it became possible to use several men or women to turn the stones. At the same time animals probably began to be

Courtesy of Near East Relief.

AN EARLY TYPE OF STONE MILL KNOWN AS THE QUERN

Picture shows two Near East orphans operating the mill which is composed of the upper and nether millstone. When people had to use mills like this it required a large amount of labor to crush the grain and less time was left for producing the comforts of civilization.

employed, as they could be hitched to the end of the lever and turn the large upper millstone as well as men. Thus we find that animal power was used in crushing as well as in producing grain in very early times.

The art of sifting was later in developing than the crushing of grain. It did not develop until man understood the art of weaving. Sieves made of horsehair were probably among the earliest bolters used. The discovery in dietetics that the inside of the grain tasted better when eaten by itself than when eaten in connection with the outside bran coat stimulated the desire for some means of sifting. The desire for sifting was also stimulated by the fact that chips from the millstones were often mixed with the ground meal; also to ease the milling process coarse sand was mixed with the grain. These were not palatable ingredients, and it is easy to see how the desire arose for removing this coarse sand as well as the bran.

One of the first uses of water power was in connection with the crushing of grain. An early device employed the principle of the lever. On one end was fastened a vessel and on the other a stone which served as the crushing implement. This lever was balanced on a fulcrum in such a way that the vessel was placed under a small waterfall and the stone used for crushing over another stone which was hollowed out to hold some grain. It was so adjusted that when the bucket became full it lifted the stone and then it tilted, spilling the water. This allowed the stone to fall down of its own weight, thus crushing the grain. This device is

said to have been used by some Indians in North America.

The first great advance in the use of power for milling was made when the water wheel was invented, which was probably about 100 B.C. This permitted the use of water power to turn a large upper millstone. With the advent of this invention came one of the first manufacturing processes, that is, where certain people are employed in making necessities for other people in return for other commodities. The use of wind as a source of power for milling was a much later development. Water power was more steady and sure than wind power, and then it took more mechanical ingenuity to build towers for holding the windmills. For this reason as long as water power was available for milling wind was not used to any great extent.

The greatest drawback to the use of water power was that the mills were limited to the locations in which this power was found. As means of transportation were crude and inefficient, it meant that mills could never be very large. They could only serve a limited area, and for this reason mills turned by animal or man power were in use in districts where water power was not available long after water power mills were invented.

As long as water power was the only power available aside from man or beast there was no competition among mills and hence little incentive to improve. The invention of the steam engine by James Watt in 1769 marks a new era in the industrial world and since milling was one of the earliest manufacturing industries it was one of the first to

be benefited by the use of steam power. Watt himself was largely responsible for the first application of steam power to flour milling. A mill equipped with 20 pairs of millstones was built on the banks of the Thames and began operations as early as 1786. It was run by two 50 horsepower engines and was probably the largest mill in the world's history up to this time. As soon as the advantage of applying steam power to milling was demonstrated, a large number of mills were built, not only in England but in continental Europe as well. However, before the development of transportation the mills had to be limited to the needs of the cities in which they were located, hence the trade was slow as long as the problem of transportation was unsolved. The first railroad was opened in England in 1825 and railroads followed in other European countries a few years later. With the development of transportation, mills larger than necessary to serve the cities in which they were located began to be built and at this time we have some of the beginnings of modern milling.

The automatic system which does away with laborious processes of carrying the ground products from one part of the mill to another was introduced about the same time that steam began to be used as a source of power in milling. The first automatic mill was invented by Oliver Evans about 1785. Before his time it was necessary for the miller to collect the ground product below the millstones and then carry it on his back to the sifter or any other machinery used in connection with the milling process. Evans invented the screw conveyer which

could move grain or ground products horizontally from one part of the mill to another. He also invented the elevator[1] which would carry from a lower level to a higher, and also the hopper, by means of which the grain could be fed in an even stream into the grinders. By means of this the ground product was elevated from below the millstones to the upper stories, and distributed where it was wanted, and then the product descended by gravity from one machine to another. This principle, very much perfected, is in use to-day and it has had more to do than any other thing in reducing the amount of human labor connected with milling.

Stones were used as grinders in the first mills in America, and they were not replaced by rollers until after the Civil War. The stones were first replaced in the larger mill centers and much later in many smaller mills.

When wheat is crushed between stones, one rotated on top of the other, the bran as well as the germ receives a rather rough treatment. Particles of bran are made fine enough to pass through the bolting cloth, and so give a darker color to flour. The stone process worked fairly well as long as soft wheat was principally used for milling. Hard wheat was not raised to any considerable extent in the United States until several years after the Civil War and with the coming of hard wheat a new problem faced the miller. In reducing the endosperm or inside por-

[1] Note. It is necessary to keep in mind that the word "elevator" is used with two entirely different meanings. The wheat storage department of the mill is often called the elevator. As here used "elevator" refers to the device which lifts by means of cups fastened on an endless belt wheat or ground products from a lower to a higher level.

tion of the kernel to flour by means of the stone process greater difficulty was found with hard wheat than had been experienced with the soft wheat. The hard wheat was more brittle and the outside bran coat was more easily pulverized. For this reason millers at first did not like hard wheat. Hard wheat flour, which is now the preëminent bread wheat flour, was at first sold at a discount because it was much darker than flour made from soft wheat. The first improvement made in grinding hard wheat came when it was discovered that the hard wheat kernel could be mellowed and the bran coat could be made relatively tougher by the addition of water. This process is known as "tempering." Another step was the substitution of high for low grinding in connection with milling hard wheat. This had to a certain extent been used in connection with grinding soft wheat, but it was found more necessary in connection with the hard wheat. High grinding means that the stones were set so as not to finish the crushing of the kernel in the first operation. It was first ground partially, then the product was sifted and what did not pass through certain mesh sieves or bolting cloths was passed through other pairs of stones set a little closer. This process was repeated again and again until no more endosperm could be ground off from the bran and the endosperm was reduced to as fine flour as was desired.

One of the most important contributions to the progress of milling was the invention of the middlings purifier. In high grinding a large portion of the endosperm is first reduced to a granular condition known as "middlings"; that is, material between

the wheat and the finished flour. Some middlings are nearly pure endosperm, others are endosperm with adhering bran snips. Mixed with all these are fine bran fragments or flakes which can be removed only by air currents. The middlings purifier made it possible to remove these bran flakes and so make a higher grade of flour than was ever known before. This machine was introduced into the United States shortly after the Civil War.

The gradual reduction process achieved its greatest development with the introduction of steel rolls for milling. Steel rolls were not used very extensively in America until after the Civil War. The first roller mill on record was patented in 1775. This used the gradual reduction process, or the process of high grinding. The first roller mill which was a success was established by Sulzberger in 1846.

The reason for the slow displacement of stones by rolls in milling was not due to the fact that the principle of the operation or that the advantages of the use of rolls in the gradual reduction process were not known. It was simply because methods of power transmission had not been developed. As long as water was the main source of power it was easier to make a water wheel turn a large stone than to make the water wheel turn a number of rolls. The same is also true of the early use of steam power. It was easier to have the steam engine turn a few large stones rather than many pairs of rolls.

At the present time rolls are universally used in all large flour mills. The only use for stones at the present time is in some districts for making Graham flour or for grinding corn meal. The process of

roller milling as now developed is one of the leading industrial arts. While the fundamental principles employed are few and rather simple, the processes and refinements are long and complicated. These will be described in the next two chapters.

CHAPTER VI

PREPARATION OF WHEAT FOR MILLING INTO FLOUR

In former times when flour was made by some of the crude methods mentioned in the last chapter, there was little preparation of the wheat previous to the milling process. Even to start with, the wheat was not as clean as the farmer now obtains it from his threshing machine. The threshing was done by flails or by tramping with animals and the straw was removed by crude methods of separation. To remove chaff and other dirt, wheat was either thrown by a "winnowing shovel" against the wind or poured from a vessel held high so as to allow the wind to drive away the chaff. "Like as a chaff which the wind driveth away." The modern threshing machine does a good job of cleaning but the wheat as it comes from this machine is far from clean enough to mill into flour which will meet modern standards.

As we shall see in what follows, preparation of wheat for milling is rather an extensive process. In fact, it may be said to be a science or an art in itself. In a certain sense it may be said that the preparation of wheat for milling begins with harvesting, threshing, and storing, as these all have an effect

upon the qualities of wheat. However, by preparation of wheat as here considered is meant the preparation which it undergoes in the mill.

From such humble beginnings as were mentioned in Chapter V the milling industry has grown until it is one of the major manufacturing industries of the world. A major industry in the United States is one which has an annual turnover of one billion dollars or more. The figures given by the Census of 1920 rates the milling industry as the second manufacturing industry in the United States on the basis of the value of the raw materials and sixth on the basis of the value of the finished products. There are at the present time between four and five thousand flour mills in the United States, but about one thousand of these mills grind between 85 and 90 per cent of the total flour produced. This means that the larger number of mills are very small, probably mills which serve a local trade, and it also means that most of the flour is manufactured in the mills of the larger size. Of the total 800,000,000 bushels of wheat produced annually as an average in the United States the mills use about 600 million bushels to manufacture flour and feed. Most of the rest is exported or used for seed. In a fairly good milling year all the mills produce around one hundred thirty million barrels of flour. The barrel is the unit of measure used in connection with flour and it is equal to one hundred ninety-six pounds. In making this flour somewhat over five million tons of feed in the form of bran and shorts are obtained as by-products.

There are four main departments in a modern

flour mill: the mill proper, the wheat storage bins also called elevators, the testing laboratory, and the office. The storage bins are usually huge tanks or bins in which to store large quantities of wheat so as to have a constant supply for the mill. The main function of the office is to buy the wheat and sell the flour and feed produced by the mill. In the laboratory every bin of wheat is tested by baking and by chemical methods. A modern flour miller must know the qualities of the wheat he uses for milling and he must also know how successful he is in converting this into flour of a quality demanded by his trade. Without good wheat he cannot make good flour, and he must know that the milling processes are such that flour of acceptable quality will be produced. In other words, he must know that the flour will satisfy all reasonable demands before it leaves the mill.

One of the first requirements demanded of a modern flour is that it shall not vary in quality from one day to another, and in order to make such flour the wheat must be uniform. To obtain such wheat it is necessary that it be selected from a large area so that variation and unevenness in quality due to local conditions may be balanced in the process of wheat blending. For this reason the wider the territory from which a mill obtains its wheat the more sure is the miller of having wheat which he can blend in such a way that a uniform flour will be produced. The storage elevators have facilities for unloading the wheat from freight cars or boats and have also capacity for storing large supplies of wheat. They also house machines for the preliminary cleaning.

The cleaning is finished in the mill proper, where the wheat is converted into flour and feed.

Usually a mill devotes itself to the milling of a certain class of wheat. Which class this shall be depends both on the location of the mill with reference to the territory from which it obtains its wheat most advantageously and on the demands of the trade to which the mill caters. Mills so located that they can obtain soft wheat, cater to a trade which desires soft wheat flour for making pastry, crackers or self-rising flour. Mills so located that they can obtain hard wheat cater to the trade which demands the flours best adapted for making light bread by the process of yeast fermentation. Some large mills are so equipped that they can use either hard or soft wheat and hence cater to both classes of trade. A few mills devote themselves to grinding Durum wheat, which because of its hardness produces a very granular flour called "Semolina." This flour is used in the manufacture of macaroni and spaghetti.

Choosing one class of wheat, such as hard or soft, is the first step in wheat selection, but this does not insure uniformity, since wheat within the same class, such as hard or soft, white or Durum, may not be uniform in quality. It has been pointed out in Chapter IV that quality within the same class of wheat is influenced by local climatic conditions, soil, and variety. The composite character of climate, such as rainfall, temperature, rate of evaporation, wind velocity, and humidity vary from year to year, and even from place to place within the same general wheat section. It has also been pointed out that heavy, light, rich, or poor soil influences quality. As

this varies not only from section to section but within the boundaries of the same farm, it follows that wheat obtained even from the same local shipping point will vary in quality.

Success in holding trade depends largely on producing a flour which has the same quality at all times and production of such a flour may be said to be one of the main demands made on a mill. Such uniformity can only be secured by having wheat of constant quality. Because wheat of the same class varies from one district to another and from one year to another, the only way to have uniform wheat is to obtain the supplies from a large area and then blend the different kinds of wheat in such a way that uniformity is secured. In doing this the larger mills have an advantage over the smaller ones because of the large volume of wheat used they are able to select from a larger area. The reputation of some well-known flour brands is not due so much to inherent superiority over some other less-known brands but simply to greater uniformity. Some of these flour brands maintain such a remarkable uniformity that they may be said to be the same to-day, yesterday, and forever.

This uniformity is particularly advantageous to the customer or user. The baker or housewife becomes accustomed to the best way of handling a certain flour and obtains good results. If a change is made to another flour of equally good quality but simply different, it is necessary to make a slight change in handling the flour if equally satisfactory results shall be obtained. As a rule people are averse to changing their methods. They prefer to use the

methods which have given them success. Unwillingness to adapt the method suited to the flour has been the cause of much blame when the flour was not at fault in any way, but simply that the method was not suited to that particular flour.

The first step in the process of wheat blending is to gain a knowledge of the quality of wheat grown in the territory from which it is to be obtained. This requires a comprehensive study of the conditions of the growing crop and the testing of the wheat from different places. As soon as a new crop is harvested, threshed, and gathered into local elevators, the mills start to test the quality of the new crop. Samples are gathered from different country elevators and taken to the mill, where they are tested by various methods. In this way it is learned that wheat in a certain area is suitable to blend with wheat from another area. On the basis of this knowledge the wheat buyer obtains wheat of such quality from different places that it is possible for the miller to make a satisfactory blend. To illustrate: A certain area may have wheat which is much stronger than necessary. Another area may have wheat which is much too weak. By getting wheat from both of these areas it is possible to make a blend which will produce a satisfactory flour.

As soon as the wheat arrives at the mill samples are taken from the different cars and tested. The protein test has recently gained great prominence and is used more than any other chemical test. Amount of moisture, test weight, color, plumpness and general appearance as well as other physical characteristics are also taken into consideration.

Sometimes samples are milled on a small experimental mill and the flours baked. Before the development of the modern cereal laboratories the testing was done by the miller in charge of wheat blending simply by his judgment, but now the wheat in all large mills is binned on the basis of the laboratory tests, and in this way each bin is filled with wheat of a certain quality. When the wheat is transferred from the bins to the mill proper, a certain per cent is taken from each of several bins and mixed or blended. By pursuing such methods it is possible to feed into the mill a wheat stream of uniform quality. The success of the operation of blending determines whether the mill shall be successful in producing a uniform flour from day to day.

For large bakers a uniform flour is an absolute necessity. This is so important that they usually do not take their chance on a flour produced by any one mill, even though the mill takes all possible care in securing uniformity. In order to be absolutely sure of uniformity they obtain flour from several mills and then blend the flour.

Wheat cleaning in the modern sense did not exist in ancient times any more than did wheat blending. At the present time wheat must be made clean enough to eat before it is ready to be milled. Wheat cleaning in a modern mill is an elaborate process. The modern grain threshing machine does work much superior to the ancient method of threshing when this was done by a flail or by tramping with animals. The main work of the threshing machine is to separate the grain from the straw and the chaff, but wheat cleaned in this way is far from clean

enough to mill into a flour that will satisfy the requirements of modern trade.

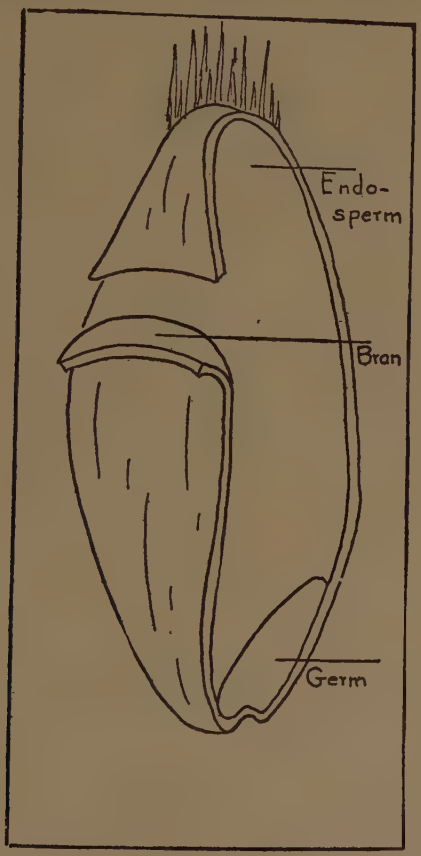
The principal impurities in wheat are seeds of other grains, weed seeds, chaff, dust and a nondescript variety of material accumulated while handling the wheat in transit from the farmer's bin to the mill elevator. The loose material is removed by a machine which in principle is the same as a large fanning mill. Part of the impurities are removed by gravity when the wheat passes over sieves. Some have openings large enough to allow the wheat to pass through but several retain the larger particles and others have openings which retain the wheat but allow weed seeds, sand and all particles smaller than wheat kernels to pass. Part of the light impurities are removed by suction with strong air currents. In this way all the material both larger and smaller or lighter than the wheat kernels are removed. Some weed seeds as well as seeds of other grains have so nearly the same size as wheat kernels that separation by means of sieves cannot be effected. For such separation, machines are used which take advantage of the fact that these seeds do not have the same shape as the wheat kernels. The wheat is passed over a series of discs in which are miniature cups. Some of these cups are just large enough to lift out wheat kernels, but will leave larger particles, principally seeds of other grains. Some cups are of such a size that they will take out smaller weed seeds and leave the wheat. In this way it is possible to secure a very effective separation.

Sometimes wheat contains materials which can be removed only by washing in water. This is particu-

larly true when wheat contains stinking smut or bunt. Such machines must not only wash the wheat, but after washing, the surplus wash water must be removed. The water is removed by centrifugal force, accomplished by throwing the wheat around by means of beaters or paddles which revolve rapidly inside a drum made of perforated metal. In England and on the continent of Europe wheat washing is used much more extensively than in the United States, one reason being that these countries use some wheats which have been threshed in rather primitive ways and the wheats have also been contaminated while in shipping.

It is also necessary to remove all materials of metallic nature such as nails, screws, or other particles of iron which have found their way into the wheat from farm machinery, wagons, freight cars or in other ways. This is done by passing the wheat over strong magnets. If these pieces of iron were not removed they would cause serious trouble when the wheat gets to some of the machines used in the last stages of the cleaning process as well as in the milling machines.

The foregoing machines can be said to remove practically all the material which is loose or does not belong to the wheat kernel itself. Wheat cleaned in this way, however, is not ready to be milled into flour which will meet present-day standards. On the end of every wheat kernel are found some very small, fine hairs. If they were not removed they would be broken into such small pieces by the rolls in the mill that they would pass the flour sieves and get into the flour. The result would be a specky,

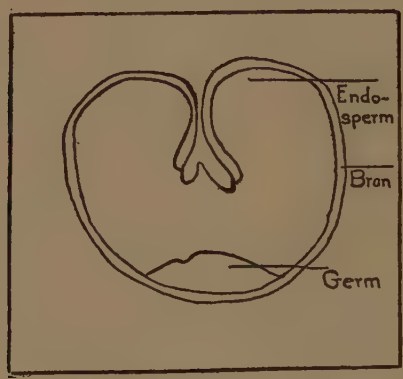


THE THREE PARTS OF THE WHEAT KERNEL.

The wheat kernel consists of about 84 per cent endosperm or floury inside portion, 14.5 per cent outside bran coat, and 1.5 per cent germ. The purpose of milling is to separate the inside endosperm from the other two and convert it into flour.

dark-colored flour which does not satisfy modern demands. The wheat kernel has also a crease half as deep as the short diameter or thickness of the kernel and running lengthwise. This serves as a place for the lodgment of dirt which is not easily removed by the machines mentioned before.

To make wheat clean enough to mill it must be scoured. A wheat scourer is essentially a long drum



A Cross Section of the Wheat Kernel.

This shows the relative position of bran coat, germ, endosperm, and the crease.

or cylinder made of perforated metal, inside of which are paddles which revolve very rapidly. When wheat passes through this machine it receives a very severe beating by these paddles and also a rubbing against the perforated metal in the wall of the cylinder, and also by attrition of wheat against wheat. This process breaks off the fine wheat hairs, knocks out any dirt that may be lodged in the crease and loosens

any material not previously removed. The loosened material is drawn off by air suction.

All fine material removed in wheat cleaning by air suction must be collected, otherwise the dust would cause serious trouble. The dust is gathered in dust collectors. One type removes the dust from the air by means of cloth sieves on the same principle as a suction carpet sweeper. Another type removes the dust by allowing it to settle in large cone-shaped dust collectors made of sheet metal. Unless every mill had an efficient system of dust collecting it would not only be very disagreeable for the workers in the mill, but there would also be great danger of dust explosions. At the present time the dust is so efficiently collected in a modern mill that very little or none whatever is in evidence. At the great dust explosion which took place in Minneapolis, Minnesota, 1878, eighteen lives were lost, but since that time only four lives have been lost in flour mills. Very serious dust explosions, with loss of many lives and much property, have taken place since that time but they have occurred in establishments other than flour mills; mostly in coal mines, grain elevators and in starch factories.

When mills first began to grind hard red spring wheat or hard red winter wheat they found that the flour obtained was of a darker color than that produced from the softer wheat raised further east. Because of this dark color the flour from hard wheat was at first sold at a discount in comparison with soft wheat flour. The reason for this was that the kernels of the hard wheat were so brittle that particles of bran small enough to pass the flour sieves

were produced in the different processes of grinding. This difficulty was overcome when millers learned the process of wheat tempering.

In order to understand the need for wheat tempering it is necessary to know some essential facts about the wheat kernel. This consists of three main parts: the bran coat, the germ, and the inside endosperm or floury portion. The art of milling depends on the fact that these three parts differ in relative toughness or friability. The problem of milling is to remove the outside bran coat, grind the inside endosperm into flour and separate out the bran and the germ. If all three parts were equally friable there could be no such thing as milling as we know it today. There could be only crushing of the grain and no subsequent separation. The bran coat and the germ are less easily pulverized than the endosperm. With this in mind, we can understand one of the main effects of wheat tempering, which consists in adding a certain amount of water to the wheat, the amount depending upon its dryness and hardness, mixing the two intimately and then allowing the wheat to stand in a bin until the water has thoroughly penetrated the wheat kernel. When water is added to the wheat, the bran coat is made tougher, and this effect is probably the reason for calling the process "tempering." Making the bran coat tougher prevents the production of bran specks fine enough to go through the bolting cloth. After millers had put into practice the tempering of hard wheat they found that it had an additional beneficial action on the endosperm. The addition of water mellows the endosperm and acts upon the protein in

such a way that the gluten of the flour has a better quality.

As a finishing touch in the preparation of the wheat for milling it is usually given another scouring after the tempering. When wheat has thus been prepared; so blended as to be uniform; when it has been so thoroughly cleaned that it is clean enough to eat; when it has been tempered so that the miller can effect a good separation of the bran and germ from the endosperm and grind this into fine, pure, white flour; then the wheat is ready for the milling process. Only by taking such pains in the preparation of wheat for milling is the miller able to produce a flour which will give satisfaction to the housewife and the baker.

CHAPTER VII

THE MODERN PROCESS OF MILLING FLOUR

In former times, as was shown in Chapter V, milling was a very simple process, as all that was done was to crush the wheat kernel and then sift out the bran. There was no such preparation of the wheat for milling as is practiced to-day. Milling has become a very intricate process, one which men spend years in learning. The object of this chapter is to give the reader a general idea of the milling process. As here presented it may seem complicated to the average reader; to the professional miller it will seem very simple. In only one brief chapter it is possible to touch on only the main steps. Milling as practiced to-day is a gradual reduction process which means that the wheat is partially ground in successive installments, and after each grinding the material is sifted and separated into several products of different sizes which are reground and sifted again. The different steps of grinding, sifting, separation, and regrinding is repeated again and again until the endosperm is reduced to the required degree of fineness and no more flour can be ground off from the bran coat.

The purpose of milling is to separate the endosperm or the floury portion from the bran coat and

the germ and reduce the endosperm to fine flour. Such separation would not be possible if the endosperm was not more friable than the other two parts, or in other words, if the bran coat and germ were not tougher than the endosperm. Modern trade demands not only a flour that is clean and white, but also a flour of good keeping qualities. Such a flour is not possible unless the miller is successful in effecting a thorough separation of the endosperm from the other two parts.

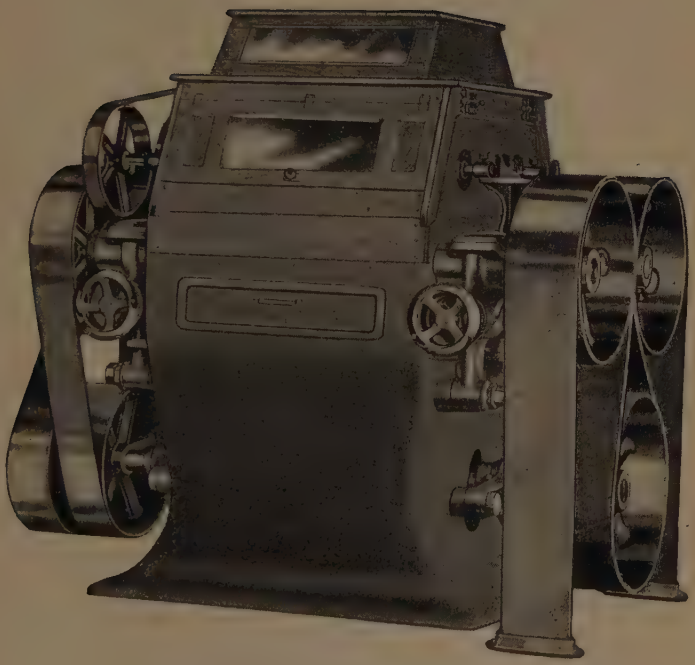
When wheat has been thoroughly cleaned as was described in the last chapter the bran is clean as bran, but if particles of the bran are reduced to such fineness that they get into the flour, this will have a dark, dirty gray color and this is objectionable to many people because in general they associate such a color with impurities. The germ is rich in fat. When the kernel is crushed the germs are bruised and as soon as this happens the enzymes or ferments which are naturally present in the germs are activated. The result of this is that the fat becomes rancid and this in turn imparts an objectionable odor to the flour. The germ would be good material for use in the preparation of human food if there was some convenient way to keep the wheat oil from becoming rancid. As it is, the germ must be separated completely from the flour. While the endosperm is more friable than either the germ or the bran, nevertheless, these may be pulverized in the grinding process and so get into the flour. That this may not happen when the inside endosperm is reduced to flour is the fundamental reason for the elaborateness of the modern milling process.

The Roller Process

Modern milling of flour is accomplished by the so-called roller process which is so named because steel rolls are used in grinding. Rolls replaced stones in all large mills in the United States during the period of milling development which followed the Civil War. The general shape of a roll is like that of a huge rolling pin; smaller sizes being 7 inches in

A Pair of Corrugated Rolls.
This shows one pair of corrugated rolls on which the breaking is done.

diameter and 14 inches long, and larger sizes being 30 to 36 inches long and 9 to 10 inches in diameter. The giant handles or the shafts rest in bearings so arranged that two rolls are parallel to each other, and generally two pairs of rolls are enclosed in a common housing. Such a housing with its rolls and other accessories is often known as a roller mill, also as a stand of rolls. On the ends of the shafts are fastened the pulleys which turn the rolls, the power being transmitted by means of belts. The housing or stand of rolls contains a mechanism



A Modern Roller Mill Grinder

Inside this housing are two pairs of rolls and feeders which convey the material in an even stream to the rolls. The material to be ground descends from above in elevators (not shown) and after having been ground drops inside the housing to spouts below the floor. (Sprout, Waldron Company.)

for feeding the material in an even stream into the rolls.

The wheat or the partly ground products descend to the roll stands by gravity and after being ground they drop a certain distance through a spout to the lower part of an elevator which is called the boot. From here the materials are carried to the top story of the mill by means of the elevators. These are simply endless belts on which small cups are fastened. As these turn up in the elevator boot, they are filled with the material and when they reach the top and are tripped, this is thrown out, after which the material descends by gravity through spouts first to the sifters, then to the purifiers, and next to the rolls to be ground again. Some flour is produced in every grinding process and this, as soon as sifted out, is blended with other streams and sent to the flour bin.

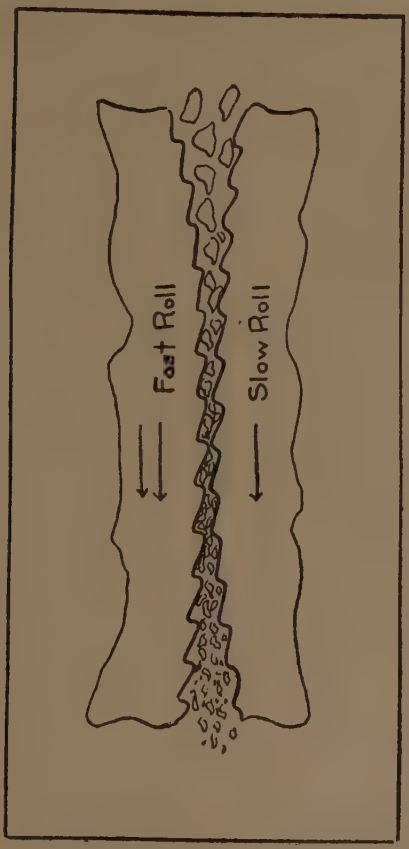
There are two classes of rolls, one called corrugated and the other called smooth. The corrugated rolls are so named because of the corrugations or grooves which run lengthwise the roll. Different rolls have different numbers of these corrugations per inch depending upon the kind of work they do. The general shape of these corrugations is like those of an old-fashioned washboard, but since there are some twelve to twenty-four per inch, it follows that they are very, very much smaller. A cross section of a corrugated roll would make the corrugations appear like the teeth of a very fine saw, only that the points of the teeth would not be sharp, but dull and somewhat rounded. The corrugated rolls are known as the break rolls. The surface of the smooth rolls has

not the smoothness of window glass, but a very slightly roughened surface something like that of print paper. These rolls are known as the reduction rolls. The rolls in each pair revolve towards each other, one at a greater speed than the other. The ratio of these speeds is known as the differential. The break rolls usually have a differential of 2½, which means that the fast roll makes 2½ times as many revolutions per minute as the slow roll. The differential of the smooth rolls is usually 1½. The slower roll is spoken of as the "holding" roll, while the faster moving roll is spoken of as the "grinding" roll.

There are seven main steps in the modern roller process of making flour: breaking, sifting, purifying, reducing, bolting, flour blending, and bleaching.

The Breaking, or Action of the Corrugated Rolls

The first step or breaking is accomplished by means of the break rolls. In most of the larger American mills there are usually five pairs or sets of break rolls, each pair or set accomplishing a part of the grinding. In larger mills it may be necessary to have two or more pairs of rolls which do practically the same kind of work and in this case they are here designated as a set. The cleaned and tempered wheat is fed into the first pair of break rolls or the first set. These break rolls crush the wheat kernel into coarse fragments. The ideal action is to break the wheat kernel open into parts so as to expose the endosperm. When this is done, endosperm particles of all sizes, some having bran snips



ILLUSTRATING ACTION OF CORRUGATED ROLLS

The grinding is accomplished by these corrugations. The fast roll revolves 2½ times as fast as the slow roll. The material is held for a moment on the corrugations of the slow roll, and as the corrugations of the faster-moving roll "pass by" it is crushed both by pressure and shearing.

adhering, are broken off, and the process also results in a very little fine flour.

As soon as the material leaves the first break rolls it goes to an elevator and is lifted to the top story of the mill from whence it descends into sifters which separate it into various sizes. These sifters are essentially stacks of sieves, the coarsest on top and those below finer and finer, the lowest one being so fine as to allow only flour to pass. The coarsest part, or that which does not pass the meshes of the top sieve or sieves, is sent to the second break rolls. The finer part, which is known as middlings, is sent to middlings purifiers as will be described later, and from the purifiers the middlings go to the reduction rolls. The middlings consists of particles of endosperm, some quite free from bran, while others have small adhering bran snips. The finest part, or that which passes through the lowest and finest sieve, is what is known as first break flour. It is very fine and starchy and contains a considerable amount of very small bran specks which give it a dark color and hence it is not put with the flour which is usually designated as first class. Fortunately very little first break flour is produced, only one or two per cent.

The action of the second break rolls is to cut off as much of the endosperm from the broken kernel fragments as possible. After the material has been ground on the second break rolls it goes to another elevator and is lifted to the top story of the building in a way similar to the material from the first break rolls. It is then sent to another sifter where it is separated into coarse branny looking material, mid-

dlings, and flour. More middlings are obtained from the second break grinding and these are richer in endosperm or potential flour material than those obtained from the first break. This sifting also yields a little flour which is known as second break flour and is of considerably better quality than that which was obtained from the first break.

The middlings obtained in this second sifting descend by gravity to the middlings purifiers, and the coarsest branny looking material, or that which does not pass the top sieve or sieves, goes to the third break. This material is richer in bran and poorer in endosperm than the similar material which went to the second break. The action of the third break rolls is to cut off more of the endosperm which still adheres to the branny looking fragments from the wheat kernel. As soon as this material has passed the third break roll it is elevated to the top story of the mill and then the process of sifting and separation is repeated. The coarser material is now more branny looking. The coarsest material is sent to the fourth break and the middlings descend by gravity to the middlings purifiers, and thence to the reduction rolls.

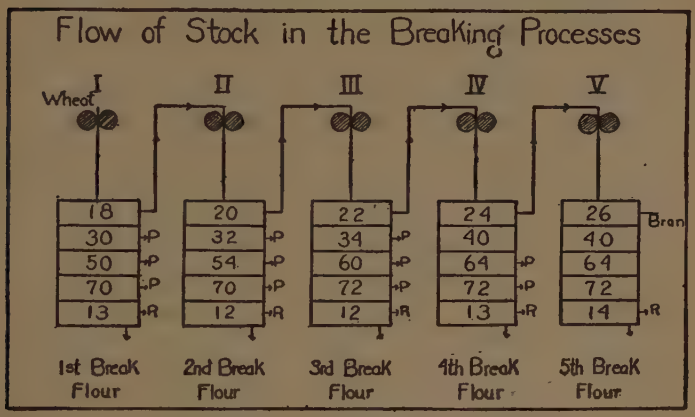
The action of the fourth break rolls is to shave off still more endosperm from the bran-like appearing fragments. After grinding, the material is again elevated to the top story of the mill where the sifting and distributing process is repeated.

The coarsest material from sifting the ground stock from the fourth break would appear to casual observers to be almost like bran, but the professional miller knows that it still contains some endosperm

which can be converted into flour. Hence this material is ground once more by the fifth break rolls. After grinding, this material is again elevated to the top story of the mill where the process of sifting and distributing is again repeated. The coarsest material from this last sifting is not ground any more as a rule but is sent to the bran duster. The action of this machine is to remove flour which adheres to the bran as dust. Such flour is of a low grade. The bran obtained at this point in the milling process is clean bran and consists of the coarsest flakes of the outside covering of the wheat kernels. It can therefore be used in human food whenever such is wanted. The middlings from the fifth break material are not as good in quality as those obtained from the previous breaks. The reason is that since the fifth break rolls must shave off the last endosperm from the bran, they are set very close together and the action is rather severe, so severe, in fact, that a considerable part of the bran is pulverized. Some of the bran which has been finely pulverized is sent into the shorts.

As the material from each break is sifted in separate sifters, three classes of materials are obtained; the coarse or overs which pass to the subsequent break, the middlings which go to the middlings purifier and the flour which passes the lowest and finest sieves. It follows, therefore, that the breaking processes produce five streams of flour, one from each break. The total break flour thus produced makes up about eleven per cent of the total flour made in the mill. The rest of the flour is obtained from the middlings, and how this is obtained will be de-

scribed later. It follows from what has been said that these streams of break flour differ in quality. The reason for this is that the rolls for each subse-



FLOW OF STOCKS IN THE BREAKING PROCESS

Shows in a very much simplified form the flow of stocks, or ground material produced in the breaking processes of a five break mill. The number of breaks are represented by Roman numerals. The cleaned and tempered wheat is fed into the first pair of rolls and then the ground material is carried by means of an elevator as shown on p. 94 to the sifters. The Arabic numbers represent the sieve or cloth meshes; the lowest sieve number omitting the last figure, which is zero. The overs from each break passes to the subsequent break and the last overs from break V is the bran. The middlings pass to the purifiers designated by →P. The finest middlings, or the overs of the bottom sifter, go direct to reduction rolls designated by →R. From each sifting of break stock some flour is obtained designated by the respective break numbers.

The flow varies in different mills. To give the complete flow from any mill would make a complicated diagram. The above is intended simply to give the general plan.

quent break following the first are set progressively closer and closer together and hence act on the bran with gradually increasing severity. As a general rule

the first break flour is the most starchy and is of a darker color than the others. The fifth break flour is more of a yellowish color than the others. The second and third break flours are considerably the best. The quality of the fourth break flour depends to a large degree upon the method of grinding. It is usually classed with the first and the fifth break flours, although it is better than either of these.

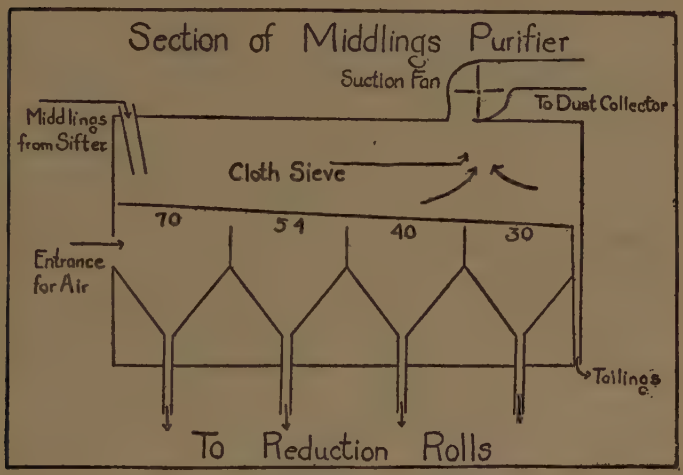
It is necessary to know that there are streams of flour differing in quality produced in the different grinding processes, in order to understand how it is possible to make up different grades of flour ground from the same wheat. As has been shown, there are four or five of these streams produced in the breaking processes, depending on the number of breaks. As will be shown later, there are usually eight or more flour streams from the reductions, depending on the number of reduction rolls used.

Purification of Middlings

It has been mentioned in the preceding that sifting the material from the break rolls gives two intermediate products: coarse material which is again ground by subsequent break rolls, and middlings which are to be purified and then reduced by the smooth rolls; and also two final products, break flour and bran. The middlings are so called because they are products obtained between the grinding of the wheat kernel by the break rolls and the final grinding of the endosperm into flour. These middlings must first be graded into different sizes, which is partly done as the middlings pass through the sifters where they are separated into various grades.

From the sifters they pass to the middlings purifiers, where they are purified as well as graded.

It follows from what was said in regard to the action of the break rolls that these middlings before sifting are of many grades, all differing in size and



SECTION OF MIDDLINGS PURIFIER

The middlings come to the purifier from the sifters by means of spouts and fall on the cloth sieve. This sieve has meshes of various size bolting cloth; finer at the head where the middlings enter and gradually coarser towards the tail end. In the section shown only four sizes are represented, in practice many more may be used. The frame which holds the bolting cloth vibrates rapidly back and forth and this causes the middlings to travel from the head end to the tail end. The fan on top produces a suction. The air is represented to enter at the head end; often it is made to enter in several places so as to give even distribution. As the middlings travel forward, the air removes the light, fluffy, branny material. This is drawn into the fan and then blown into a dust collector. As the middlings pass over bolting cloths they are graded into various sizes. The coarsest material which does not pass through the last cloth is known as tailings, or what tails over. There are a number of such purifiers in a mill, each one working on a different grade of middlings.

in quality; the quality being measured partly by fineness, but mostly by the amount of bran particles present, or in other words by the purity of the endosperm material. In the breaking process also, some of the bran is broken into very fine flakes which cannot be removed by the sifting process. They are, however, very light and fluffy and can therefore be removed from the middlings by air currents. The middlings purifier which is used for the purpose of removing such light, fluffy material was invented about the time that the steel rolls were introduced and the invention of this middlings purifier is classed as one of the important advances in the development of modern milling.

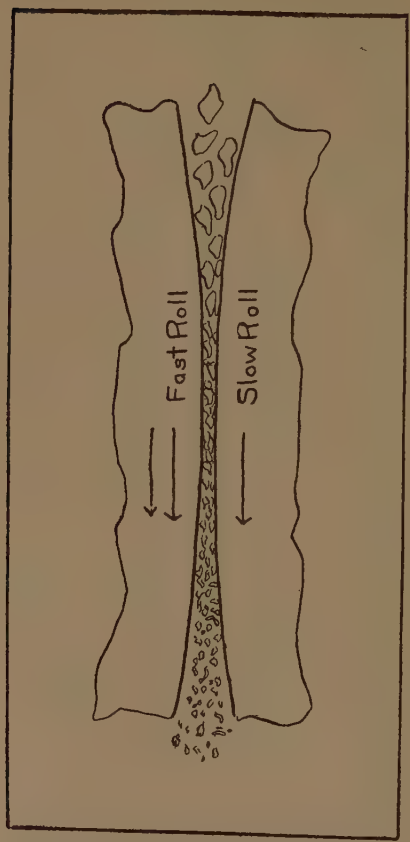
The essential parts of a middlings purifier are a housing which contains a sieve on which is stretched bolting cloth of relatively fine mesh at the head end and gradually increasing in coarseness toward the tail end, the head end being where the middlings enter the machine, and the tail end where the coarsest material leaves the machine. This bolting cloth rests on a frame which is shaken back and forth in such a way that when the middlings drop on the sieve at the head end they travel to the tail end. On top of the housing is a suction fan which draws currents of air through the middlings as they pass over the bolting cloth. These air currents lift out the fine fluffy material and send it to a dust collector. The sifting cloth, because it is of finer mesh at the head end of the purifier and gradually becomes coarser at the tail end, grades the middlings into different sizes at the same time that they are freed from the light, fluffy bran material.

The invention of the middlings purifier, the introduction of steel rolls and the learning of the art of tempering may be said to mark the beginning of modern milling. The middlings purifier was a patented machine and the millers who first introduced this machine into their mills were enabled to make a much better product than those who were not so progressive and as it was a patented device which made possible a superior product, the flour produced in a mill which contained a middlings purifier was called "patent flour." This term, then, originally meant the flour which was made from purified middlings, and such flour is to-day the best portion of the flour produced from any given lot of wheat. However, patent flour at the present time cannot be said to be always true to name, and hence the term is seldom used.

Reduction of Middlings to Flour

As the middlings pass the purifier they are freed from fine bran flakes and are graded according to size. They consist of particles of endosperm obtained from the different breaking processes. Some of these grades of middlings are nearly pure endosperm; others have more of the adhering bran snips. In the coarser grade of middlings the size is somewhat like granular corn meal. From this they grade down to almost as fine as flour. Certain of these coarser middlings are used as breakfast foods.

These purified middlings are ground or reduced to flour by means of the smooth rolls and from them the best flour is obtained. In a modern mill there are eight or more sets of these middlings rolls, and



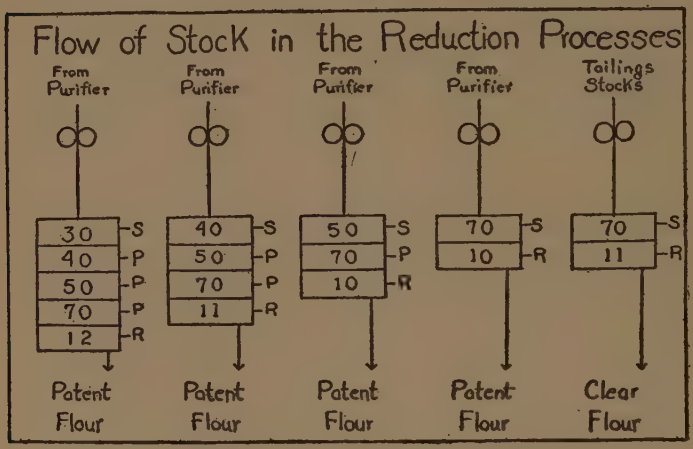
ILLUSTRATING THE ACTION OF THE SMOOTH OR REDUCTION ROLLS

The reduction of the middlings is accomplished by rolls having a smooth surface. The fast roll revolves 1½ times as fast as the slow roll. As the purified middlings pass between the rolls the slow one retards them, while the faster moving roll crushes them with a rub. This is repeated again and again.

the different sizes or grades of middlings are so distributed that each pair of rolls grind middlings of a certain size. It is essential that each pair of rolls receive middlings of a certain size, otherwise the larger particles would be crushed too hard and the finer would not be touched at all. The general plan of middlings reduction as far as it is related to the coarser middlings is somewhat similar to that of grinding by the break rolls. The coarser middlings are sent to one pair of smooth rolls where they are reduced to a finer size. At the same time that this is done some flour is produced, as well as several grades or sizes of finer middlings. The reason for the gradual process is that the middlings cannot be reduced to flour by one grinding operation. If that was attempted, the adhering bran snips would also be reduced to such fineness that they would pass the flour sieves and the result would be a dark colored flour. For this reason the middlings are ground partially several times in successive operations and at each grinding flour is produced and what is not sufficiently reduced must be ground again. Each time the grinding and sifting is repeated the proportion of endosperm decreases and the proportion of branny material increases.

The product from each grinding by the smooth rolls is elevated to the top of the mill in a manner similar to the product from the break rolls. This product is then sifted, and in sifting various grades of middlings are obtained as well as flour. These various grades of middlings go to middlings of a similar grade and size which were obtained from the breaking processes. The plan is to reduce the mid-

dlings gradually. The action of the smooth rolls is crushing with a rub, or a squeeze and shear action. The slower moving roll holds the middlings particle



FLOW OF STOCKS IN THE REDUCTION PROCESS

The above represents in a very abbreviated form the flow of stocks in the reduction processes. The middlings, after passing through the purifiers, pass to the different reduction rolls, the rolls to which they are sent being determined by their size and purity. For the sake of simplicity only five pairs of rolls are represented in the diagram. Each grinding of middlings produces three classes of products: flour which passes the lowest or finest sieve; feed, or shorts, which are the overs from the top sieve; and finer middlings. The middlings which are produced in the breaking processes may be called primary, and those produced in the reduction processes may be called secondary middlings. These secondary middlings, except the very finest, are also sent to the purifiers. The finest middlings, or the overs on the lowest sieves, are sent direct to reduction rolls. Thus certain portions of the middlings may have passed the reduction rolls several times before they are reduced to flour or shorts.

The finest or best grade of flour is obtained from the reduction of purified middlings. Near the end of the process, or when the middlings are too fine to be sent to the purifiers, the reductions result in a poorer grade of flour. This has about the same grade as the flour from the first and last breaks and is blended with them to produce what is known as clear flour.

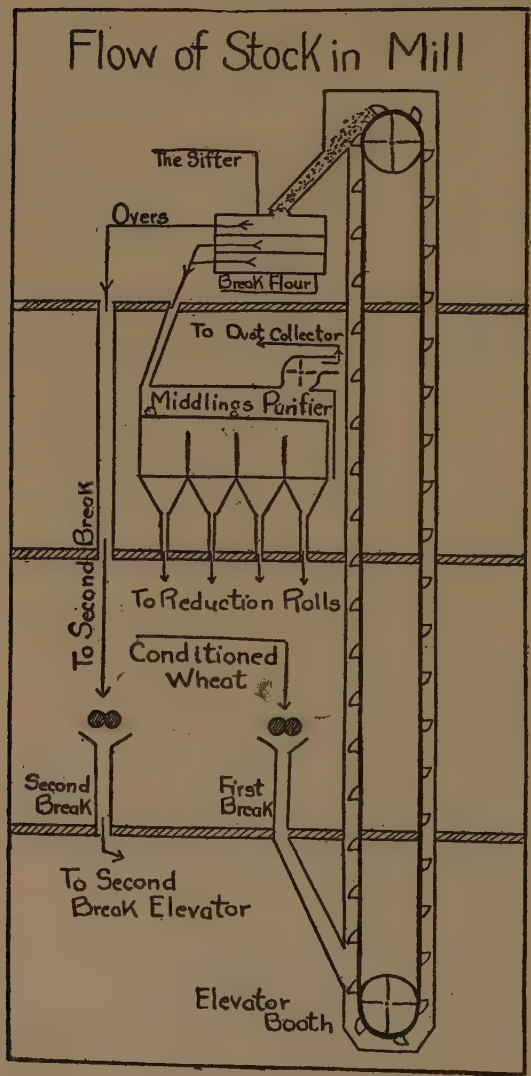
for a moment while the faster moving rolls presses it and at the same time crushes it with a rubbing action.

It is this action of the smooth rolls which produces the granular flour. It is also this action of the rolls which makes it possible to crush off the adhering bran snips from the endosperm without reducing this bran snip to such a fine condition that it will get into the flour.

The germ is loosened in the breaking process. It is of such a size that it gets into the coarser middlings and hence these are sometimes known as germ middlings. When these middlings are acted on by the smooth rolls the germ is flattened because it is tougher than the endosperm and in this condition it is possible to sift it out and prevent it from getting into the flour.

Bolting the Flour and Making the Flour Grades

It has already been stated that after each grinding on the smooth rolls the products are sifted or bolted. Bolting cloth is made of silk. The coarser cloths have 30, 40, 50, up to 70 meshes per linear inch and are used in grading middlings for subsequent grinding. The finer cloths have 109 to 125 meshes per linear inch and are used for bolting out the flour. The bolting cloth which has 109 meshes per linear inch is known as No. 10, and it has accordingly 11,881 openings per square inch. Nos. 11, 12, 13 and 14 are finer cloths and hence have more meshes. No. 10 is the coarsest cloth through which flour is sifted. This means that the flour particles which



See caption on opposite page.

Flow of Stock in Mill

The cleaned, tempered or conditioned wheat comes from the tempering bin to the first break rolls. The rate at which the wheat is fed in to this roll is governed by an accurate regulating device. The ground material from the first break descends through a spout to the elevator booth where it is scooped up by the elevator cups fastened on an endless belt, and are carried to the top. As the cups turn, the material is thrown into a spout and carried to the sifter. Here it is separated into three classes of products: overs, middlings, and first break flour. The overs are carried by means of a spout to the second break, where, after they are ground again, they go to another elevator and start on a process of separation similar to the material from the first break.

The middlings first go to the middlings purifier where they are freed from branny, fluffy material and are also graded into various sizes. From the purifier the middlings go by means of spouts to the various reduction rolls. The coarser go to one pair of rolls, those a little finer to another, and those finer yet to still another, and so on. After the middlings are ground by the various reduction rolls the ground products are elevated to the top where they are sifted and divided into various products, some of which are reground.

Each grinding produces some flour. The break flour is blended with the flour obtained from sifting the ground products from the other breaks. The same is done with the flour from the reductions.

Thus milling consists in a repetition of grinding, elevating, sifting, grading, purifying and regrinding, done over and over again with variations until the wheat has been separated into three classes of products: flour, bran, and shorts.

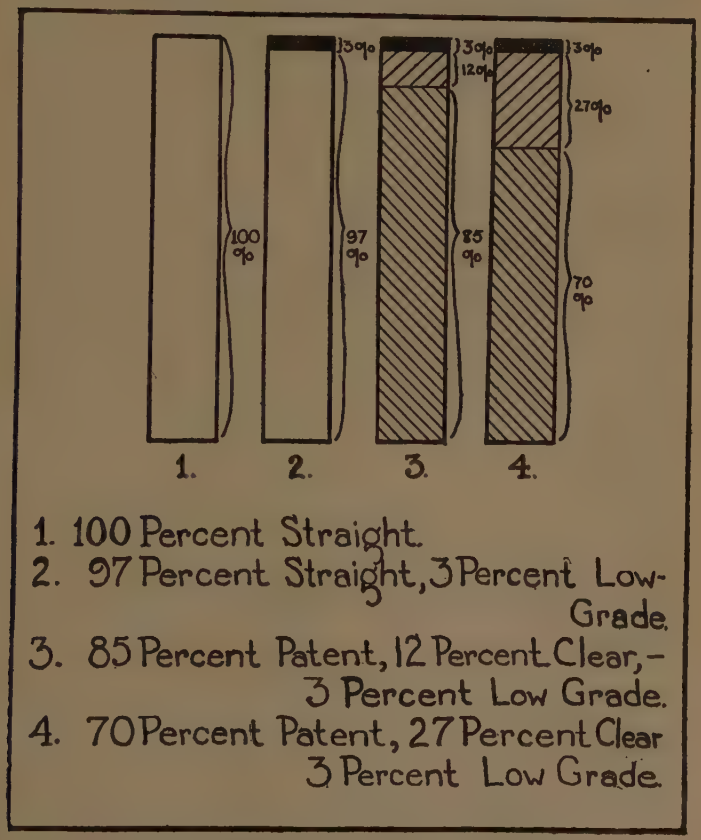
have passed No. 10 cloth are so small that they must pass openings of such a size that there are nearly 12,000 of these to one square inch. As the thread in the bolting cloth is of nearly the same diameter as the opening of the cloth, it can be shown that it would take over 40,000 flour particles to cover one square inch of surface. This gives some idea of the size of flour particles.

Whenever the material from a reduction is sifted, some flour is obtained. The coarser part which still contains endosperm as well as adhering bran snips is sent to the next pair of rolls which in grinding produces finer middlings. By the repetition of this process over and over again, together with the sifting after each grinding, there is finally obtained a material much finer than bran and more of a gray color. This is what is known as "shorts." These shorts contain a considerable amount of flour material which the millers are unable to remove as well as the fine bran fragments and also the germ.

From what has been said it follows that there are a large number of flour streams obtained in the reduction of middlings. There are at least eight or more, depending on the size of the mill and the elaborateness of the milling process. As with the flour produced in the breaking processes the flour produced in the different middlings reductions differ in quality. Those streams which come from the first several reductions of purified middlings are much better than those which are obtained after the middlings have been treated so that there is comparatively very little endosperm left.

Flour grades are technically known as straight,

patent, clear, and low grade. If all the flour streams made in the mill are mixed or blended this would be 100 per cent flour. This could be called a straight flour. Usually, however, some of the poorest streams are not included in the so-called straight flour. These poorest streams are made up of flour obtained from



BARS REPRESENTING FLOUR PERCENTAGES

some of the very last reduction processes or from some of the suction processes which collect flour dust. These usually amount to about two or three per cent of the total flour. Such flour is known as low grade, and the rest would be what is known as straight.

Patent flour which is true to name is produced by blending or mixing the streams of flour which are obtained by the reduction of purified middlings. Patent flour made up in this way would be known as short patent. If such short patent flour is made, then it is necessary to make up a class which shall contain the break flour and also some of the streams which are obtained from middlings which have been reduced several times. Such flour streams which are not good enough to go into the patent, and too good to go to the low grade, are blended into what is known as clear. In discussing the break flours it was noted that certain of them are much better than others. When the best break flours are blended with the flour streams obtained from the reduction of purified middlings, then the flour is known as a long patent. In such a case less clear flour is obtained and this is known as second clear.

It follows from what has been said that it is possible in any complete mill to make several grades of flour from the same wheat. Some of the flours from purified middlings are better than others. Thus, while fundamentally the quality of flour as a whole depends upon the quality of the wheat, yet from any one wheat can be manufactured four or more grades of flour. The percentages of various grades are illustrated on page 97. Bar 1 represents 100

per cent straight or all the flour produced in the mill. Bar 2 represents 97 per cent straight and 3 per cent low grade. Bar 3 represents 85 per cent patent, 12 per cent clear and 3 per cent low grade. Bar 4 represents 70 per cent patent, 27 per cent clear and 3 per cent low grade. A shorter patent, such as 65, may also be made. Sometimes when short patents are made the clear flour is divided into first and second, the better streams going into the first and the poorer into the second clear. Sometimes mills make what are known as stuffed straight and cut straight. Suppose a mill has been making patent and clear, and that there is a good demand for the patent but not for the clear. Suppose also that there is a good demand for a strong bread flour. This latter can often be made satisfactory to a certain class of trade by mixing the clear with the straight, and flour blended in this way is known as stuffed straight. If a few of the better streams from the total flour produced are taken off the flour is a cut straight. These better streams are blended into a fancy grade of flour.

A General View of the Mill

One of the most striking and remarkable facts which would be apparent to any one who visited a modern mill is the presence of so few men among the milling machinery. This is in contrast to most manufacturing processes, where men are everywhere in evidence, each one bending to his task. Suppose we go to the roll floor of a modern mill. There is a long row of roll stands all working at a great speed. Here are the giants which do the work formerly

done by slaves, prisoners, or less fortunate members of society. The wheat or stock comes to the rolls from above in spouts and the ground products disappear below the rolls. The man who is there opening small doors or openings on the roll stands, taking out and carefully examining the products before and after grinding, is the miller. Now and then he may turn or move an adjusting device. Besides this man there may be one with an oil can in hand adding oil here and there to the different bearings. This oiler may be seen on the various floors since he goes all over the mill. At times we may encounter another man, with a floor brush or a hand brush, busy removing dust from different machines or the floor. We shall find that a modern, up-to-date mill is clean; so clean that a visitor could go through and get but very little dust on his clothes.

The roll stands give the impression of being ponderous, of working at a great speed, and that they do a tremendous amount of work. The broad wide belts over the pulleys tell us that some great power not in evidence is turning the rolls. Here is the giant which has lifted a great burden from man and lightened his task.

As we go to the next floor above the rolls we come to the purifiers. The purifiers are usually arranged in a long row. They give the impression of quick but easy movement and need little attention. The men in evidence are few; a miller, a sweeper, or an oiler. Above the purifier floor is the floor containing the sifters. In contrast with the short quick motion of the purifiers the sifters execute a rapid whirling motion which makes one dizzy. The materials which

enter into these whirling hulks get a severe shaking. While the sifters are massive and whirl at a rapid rate, yet they are so well balanced that they give the impression of easy but ponderous movement. A miller may be seen here and there looking at belts and machines to see if everything is in order. He also takes out material from different spouts to note if the various machines are doing their work properly.

In going from floor to floor in a modern mill one sees a mass of spouts. The elevators are usually arranged in a long row, each one close to its neighbor. In these the stocks are carried from below the rolls to the top story of the mill. The spouts through which the stocks descend are placed at all angles and positions. It looks like a bewildering maze, but they are all arranged according to a definite plan and order. To see that the stocks move in these spouts without stoppage or "choke up" is one of the duties of the millers in charge. From the moment the wheat enters the first break roll there is a continuous movement and this must be kept going. A stoppage at any one point means serious disarrangement, and when any such occurs the men must get busy and start the stock moving.

The packing of the flour and feed is usually done on the floor below the rolls. Here the workmen are more in evidence than anywhere else. One man is in charge of each machine, and these machines, or packers, work at the will of the operator. The flour or feed comes from large hoppers above, and the machine packs them into sacks. While some men are engaged in operating the packers, others are en-

gaged in closing the sacks, either by tying, sewing by hand or by having a machine to do the sewing. Other men are busy wheeling away the sacks on hand trucks. Flour, and feed as well, are usually wheeled direct into the freight cars which are drawn up alongside the mill.

While milling is probably more of an automatic process than is true with most manufacturing industries, men must be present to see that the machines are running true, and that each machine and spout does its share of work. The large number of machines and the complexity of the mill means that a miller needs first to be a mechanic who understands machinery, and then he needs to be an artist who understands how to make the machines produce a flour of such quality as will give satisfaction.

Milling, which was in ancient times a very simple process but a very laborious one, has now become a very complex process but one accomplished with comparatively little labor. Work that was done by the less fortunate members of society now requires skill learned by years of study and practice. But the greatest transformation has come to the miller himself. The miller who used to be a drudge, slave or prisoner now is a skilled artisan who holds an important place in the modern social order.

Flour Bleaching

The endosperm of the wheat kernel contains a yellow coloring matter called carotin. As a rule this is more abundant in hard winter wheat than in soft winter wheat or even in hard spring wheat. Popular opinion favors white flour because whiteness is

associated with purity. This predilection for whiteness in flour is no doubt derived from ideas obtained from ancient methods of threshing wheat as well as of milling wheat. When these methods were in use, a dark color was associated with undesirable substances. For some reason or other a yellow color in certain other foods is also objectionable. The yellow color due to carotin cannot be removed by any process of milling; it can only be removed by the process of bleaching. There are at the present time principally four reagents used in removing this yellow coloring matter. These are chlorine, nitrogen tri-chloride, nitrogen peroxide, and benzoyl peroxide. The last reagent is in the form of a solid, and the other three are in the form of gas. These reagents are mixed with flour in a closed drum and then agitated where the reagents act on the flour in such a way as to destroy the yellow color. So far as is known, there is no injurious residue left in the flour from any of these reagents, nor has it been shown that the use of these reagents is in any way deleterious to health. When these bleaching agents were first used very vigorous opposition was encountered from pure food advocates, but in the legal trials which followed it was shown that these reagents, although by themselves poisonous, are used in such small amounts as to be perfectly harmless.

While these reagents destroy the coloring matter in flour, and so make it whiter, they do not improve flour which is dark-colored due to the presence of bran specks.

These reagents aside from destroying the yellow coloring matter also have a maturing effect on flour.

Before these bleaching reagents were used the millers always had more or less trouble when they commenced to mill a new crop. Flour as soon as it is milled undergoes an aging process which is beneficial. This process may also take place in the wheat before it is milled, but if it has not taken place then it must occur in the flour before this will prove satisfactory in the bakeshop. This aging takes a considerable time and the advantage of using bleaching reagents is that what formerly required a long time is now accomplished in a very short time. For this reason bleaching reagents are used also as maturing agents, and bleached flour is often called artificially matured flour. The government requires that whenever bleached flour is sold through interstate commerce it shall be so labeled. Sometimes the label states "bleached," sometimes "artificially matured." Both mean the same thing.

CHAPTER VIII

SOME REASONS FOR MILLING

THERE are some people who think that it is a mistake nutritionally to mill wheat. They have learned that the outer covering or bran of wheat contains a higher per cent of protein and mineral matter than the inside endosperm or the portion from which flour is made, and they have also found out that the bran and germ are richer in vitamin B. Then why should wheat be milled? Would it not be better nutritionally if the wheat was simply crushed and eaten whole? From remarks made by some sincere and intelligent people, it would appear that they believe that the miller has deliberately set about to rob the people of certain of the wholesome portions of the wheat kernel which a kind Providence intended they should have. Very often when explaining the process of milling to such people they remark: "In that way the miller takes away the best portion of the wheat." Perhaps some reader of the chapter on milling may have asked, "Why go to all that trouble when it would be better to use whole wheat as a food?"

Milling is not done for the purpose of removing some valuable constituents from the flour; one of the greatest manufacturing industries could not exist on such a basis; milling is done because white flour

has been preferred by most people to any other kind since ancient times and that preference still exists. Milling is also done for the purpose of making a product that keeps well in storage, and this is one of the most important conditions in supplying food to people who live long distances from the place of production. A third reason for milling is to provide for a greater variety in food. It may be that the first impulse to crush grain was a desire to get a food which could be chewed more easily. It is now a long time since man abandoned the use of his molars in grinding grain. No doubt teeth are made to be used, but the substitution of human molars for steel rolls will not be a "cure all" for dental troubles. Immigrants who have lived on coarse food have even poorer teeth than Americans, who are supposed to have ruined their teeth by the use of wheat bread. It will be pointed out in a subsequent chapter that lack of certain vitamins has more to do with poor teeth than anything else.

Some reasons for milling wheat are the same as lead Oriental people to polish rice. Nutrition studies have shown that the disease known as beri-beri is particularly common among people who eat polished rice. Why should people go to the trouble of polishing rice when nutritionally it would be better for them to eat the rice unpolished? Rice is the cereal grain of people who live in hot, moist climates. In such a climate it is difficult to preserve any food in storage. These people a long time ago discovered that polishing rice would enhance its keeping qualities. To be sure as time went on there came to be a little vanity in this. There was an expense con-

Roll Floor in a Large Mill

The rolls which do the grinding are arranged in two long rows. The mill is of daylight construction and the floor is concrete. (Allis Chalmers Manufacturing Co.)

nected with polishing rice, and the man who could afford to have his rice polished placed himself in a higher class than the man who could not. The desire for a whiter product came as a secondary result of the necessity of improving the keeping qualities of rice.

Modern civilization demands that a substantial portion of the food of a people shall have good keeping qualities. When primitive man ate anything and everything available, insects, grubs, animals, shellfish, fruits, roots, bulbs, vegetables and whatever else he could find, he probably did not suffer from those diseases which have come with civilization. He probably had a sufficiency of vitamins. But his existence was rather precarious, and he did suffer from hunger, and he did not develop a type of life which appeals to most people at the present time. A regular and adequate food supply is the most necessary item in any civilization. When life proceeds in an orderly way, we do not stop to think of the enormous problems involved in feeding a large nation. This was more fully realized during the World War.

One main reason, then, for making white flour is the necessity of having a product that keeps well in storage. Wheat keeps well in storage before crushing, but as soon as the kernel is crushed enzyme activity is stimulated, which means that vital forces are activated, and it is necessary to separate the fragments of the bran coat and germ from the ground endosperm in order to have a product of good keeping qualities. Because of the good keeping qualities of white flour this food product is trans-

ferred from the producer to the consumer with more economy than any other staple food article.

Another main reason for making white flour is the universal desire of people for a white color in flour. This has been born into the consciousness of people for generations. When wheat was threshed by tramping out the grain with animals, when the grain was crushed by pounding or rubbing with stones, a dark color in flour was synonymous with dirt. While the miller may know that a dark speck in flour is a particle of the outer covering of wheat, most purchasers of the flour have a different belief. In their mind dirt in general is associated with a dark hue and whiteness is a sign of purity.

The reasons for manufacturing some other food products are in a way similar to the reasons for manufacturing flour. The keeping qualities of dairy products are enhanced by manufacture and people can have a greater variety of food. Milk is a more complete food than butter, but that is never advanced as a reason against making butter. Cheese is a more complete food than butter, but it is not as universally used. Butter is valued as a fuel food and is relished because of its good flavor and pleasing appearance. It is also a good source of vitamin A and a fair source of vitamin D. Butter is almost wholly lacking in mineral matter, yet no one has used that as an argument against the use of butter. Sugar has excellent keeping qualities and it serves as a fuel food. It is universally liked because of its sweet taste and the whiteness which appeals to the eye. Sugar is a pure carbohydrate, no protein or minerals whatsoever. The lack of min-

A Row of Sifters in a Large Mill

This row of sifters does the work of sifting in a mill of 3000 barrels capacity per 24 hours. The ground materials enter the sifters from above and leave in the spouts below the sifters. (Allis-Chalmers Manufacturing Company.)

eral matter in sugar could be helped somewhat by the inclusion of the dried beet pulp, but this seems so absurd that no one seems to have thought of this as a means of supplying the mineral deficiency in sugar.

Then people want variety in diet and this desire is based on sound nutritional doctrine. "Bread is the staff of life" is a proverb which has come down to us from ancient times. Bread in former times was dried and so could be kept for a considerable time. It could be taken on long journeys, hence became known as the "staff of life." It was the main food of poor people and in time of war or stress "daily bread" became synonymous with life. Bread in the diet under normal conditions of civilization does not occupy the same place as it would during famine or war. Bread should not be thought of as a complete food. People want a varied diet and they tire of a single diet. The people of Israel became tired of the manna in the wilderness, not because it was not a good food, but because of the monotony of the diet. The only complete food known in literature was the mythical ambrosia of the Greek gods. People would not be satisfied with such ambrosia because they want variety. People's diet does vary all the way from the entirely animal food of the Eskimo to the almost exclusive vegetable diet of the tropics. There is also the diet composed almost entirely of milk products and a few cereals such as is used in Central Asia. Civilized man has opportunity to get a satisfying combination of animal and plant foods. This supply of steady and variable food is provided because of the efficiency

in production and transportation. To produce and distribute this variety of food is a problem of great importance and of enormous magnitude in any large country. To make it possible for people to prepare and have a greater variety in food is then the third reason for milling.

CHAPTER IX

COST OF MILLING TO THE CONSUMER

WHO makes this flour which constitutes at least one-third of the materials for your total food? What does he get for grinding all the flour you consume in a year? What is the cost for the use of machinery? Flour is now so common and comparatively so cheap that the miller and the mill in which the flour is produced are taken for granted like sunshine. Learn from your grocer or cook the total cost of 200 pounds of flour, since that is your approximate annual share if you are an adult in active life. Multiply that amount of money by three and you will find what the cost would be for all the raw materials of your total food if they were obtained at the same rate as flour. It will probably amount to between $25 and $35 per year or less than 10 cents a day. It would be a cheap living if all food material were as cheap as flour, but as people cannot live on bread alone there is another story to food costs. This, however, shows that all the flour modern man consumes is obtained for a song compared with that it cost people in former times, especially when figured in terms of human labor.

In this chapter we are considering the cost to the consumer of milling all the flour he eats in one

year. We will be able to see this more plainly if we compare present costs with what it cost the pioneer in this country to have his wheat converted into flour, and also what it cost the ancient housewife to do the milling. First, how much did it cost the pioneer to get his wheat converted into flour? "Father" had to load some bags of wheat into the "lumber" wagon and proceed to the mill. In pioneer days the mill was one of the first manufacturing establishments in a new settlement, and the old mill by the stream was an early landmark. The man who built the mill where the settlers could have their wheat ground was a public benefactor; he made life possible in a new country. For many people it was a day's journey to the mill and another day home. Two days for a team and "Father's" time. Then he paid the miller for doing the grinding. As money was scarce the miller was paid in toll or a certain per cent of the wheat. What did the miller do for this toll? He simply converted the wheat into flour and feed. The customer took care of all the transportation charges, there was no expense for sacks as the flour and feed were put back in the same sacks in which the wheat was brought. There was no selling expense, no advertising, no freight, no grocer's handling and delivery charges, but all these items were paid for by the pioneer in terms of the time spent in going to and coming home from the mill. While these items are now included in the final cost of the flour to the consumer, they amount to very little at the present when compared with the cost in time to the pioneer.

With all the inconveniences involved in the pio-

A Modern Large Flour Mill

This mill has a capacity of 2000 barrels of wheat flour per 24 hours. The cylindrical tanks are for wheat storage. The large windows permit the entrance of an abundance of light to all places where the milling machines are located. (Nordyke Marmon Co.)

neer's way of milling, it was a great improvement over methods used in ancient times or methods now used in less civilized countries. What was the milling bill of the ancient housewife when stated in terms of human labor? In Chapter V it was pointed out that there were three methods of grinding grain in ancient times: pounding in a mortar, rubbing between two stones, and rotating one stone upon another, employing either man or animal power. Grinding was irksome labor, and it was work that a gentleman should not do, and consequently it was forced on the women if there were no slaves. Among average folk, grinding was done daily, and was hard work which took a great deal of time and energy from the average people.

In these days "Dad" does not concern himself about milling. If he goes to market himself the grocer puts a sack of flour in his wagon or car. Very few women know anything about how their flour is produced. In town it is usually ordered over the telephone, and it is delivered in the kitchen. And the flour so obtained is the best the world has ever seen. That made by ancient methods would be accepted as chicken feed, and the pioneer's flour would not find a sale in the average home. The wife of a poor man to-day buys as good a flour as goes into the kitchen of the most wealthy.

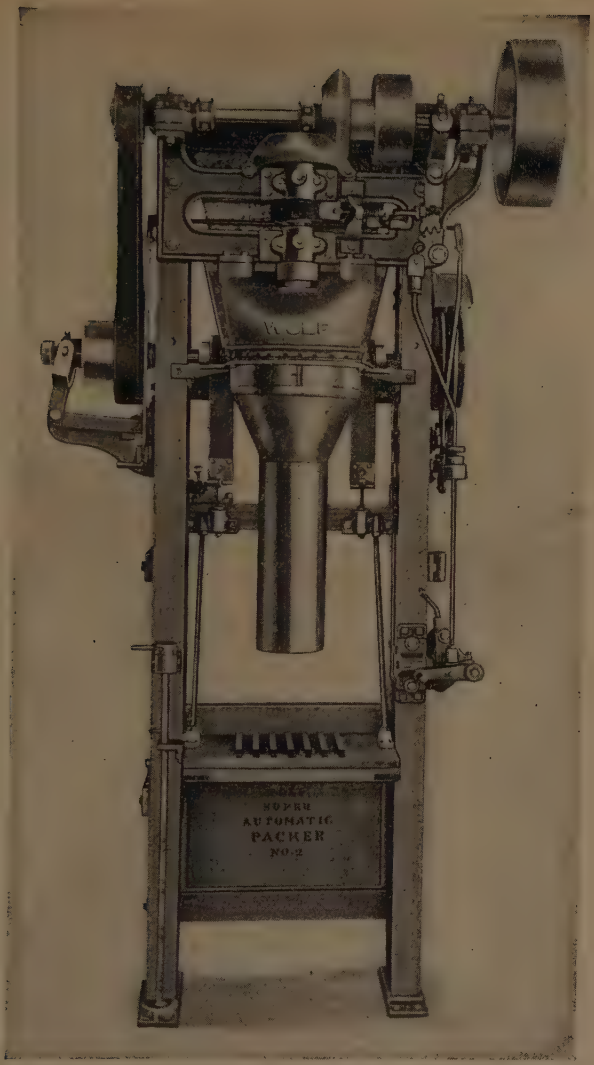
Some of the reasons for these conveniences are to be found in the fact that the flour mills were among the first, if not the first, of modern manufacturing enterprises to adopt the automatic principle which has made possible the great material advances and the great production of wealth by modern indus-

trial processes, and also to the fact that this principle has been carried to a greater degree of perfection in flour mills than in almost any other large manufacturing industry.

We will now consider the labor expense involved in the modern way of milling flour. The following figures were obtained from the superintendent of a 3,500 barrel mill; that is, a mill which has a rated capacity of grinding that many barrels in 24 hours. Since one barrel of flour is about the average adult's annual consumption, it means that in 24 hours this mill grinds as much flour as 3,500 adults consume in one year. Sometimes the figures given for mill capacity are greater than actual, but for this mill the given capacity is conservative, since it can be made to produce 4,200 barrels in 24 hours with small additional labor. In this mill it takes the following number of men, each man working 8 hours, to do the work as mentioned:

Transferring wheat from cars to elevator....	5
Work of actually grinding the wheat.....	21
Packing flour and feed and loading on cars..	41
Testing wheat and flour in the laboratory...	5
Accessory men, engineers, mechanics and helpers	12
Total.....	84

In Chapter VI it was pointed out that there are four main departments in a modern flour mill; the mill proper, the storage bins or elevators, the testing laboratory and the office. The work of the office is to do the buying and selling and its force is not included in the above figures. The other three departments are concerned with the work of convert-



A Flour Packer

In order to get the requisite amount of flour into a sack it is necessary to pack it. The packing mechanism is inside the cylinder and is shaped like a huge augur. After the sack is filled it is weighed and then closed by sewing the top together. This is done either by hand or by a machine. (Wolf Co.)

ing wheat into flour and the figures show the number of men required to do the different kinds. On this basis there are produced in this mill 42 barrels of flour for each 8 hours of man labor. This probably represents the highest labor efficiency. In many other mills of the larger size the production is from 36 to 40 barrels per 8 hours of man labor, and in smaller mills the efficiency may be as low as half of this. At 40 barrels per 8 hours of man labor it means that it takes 12 minutes for each barrel, and since one barrel is nearly the amount consumed by an adult annually, it means that it takes that much of a man's time to mill all the flour he eats in a year. This includes all the milling operations from the time the wheat leaves the freight car until the flour is loaded for shipment. There are two remarkable facts about the above figures. Less than one-fourth of the men are actually engaged in those milling operations which involve the preparation of wheat for milling and the grinding into flour. This portion of the work was the hardest by the ancient methods of milling, since after the grain was crushed most of the labor was done. By the use of automatic machines this part of the work has now been reduced to the vanishing point. If all the milling operations require 12 minutes of man labor per barrel, and if the actual grinding operations require only one-fourth of the men, then to grind all the flour one man eats in a year requires about three minutes of man labor.

The above figures take into consideration only the item of human labor in the cost of milling flour. In ancient times or even in the pioneer's day this

was the most costly item. Now it is insignificant. In ancient times the cost for equipment was very small, now it is very large. Besides labor and equipment there are a number of other expenses connected with flour milling. The Federal Trade Commission has made a study of milling costs and has arrived at the following average figures which are based on the production of one barrel or 196 pounds of flour.

Labor	$0.22
Other mill costs	0.17
Depreciation	0.04
General expense	0.22
	$0.65

These four items were included in great-grandfather's "toll." It is the actual money charge for converting into flour about all the wheat one man or woman eats in a year. The labor costs are about one-third the other costs, and the total cost of having all the wheat a man eats in a year ground into flour is just about what he would pay for a half hour's work on his car or for one admission to a fair show.

The above lists only the conversion costs. The modern city housewife wants her flour delivered in a cotton sack to her kitchen. The farmer takes it home from the grocer in his wagon or car. This entails first the cost of sacks, and second the selling expense. The miller has to show by means of advertising and a sales force that his flour is as good if not better than that of competing mills. Some milling firms have spent millions of dollars to bring their brand name before the public. In the third

place there is the freight from the mill to the grocer, as the mill may be located in Kansas and the grocer in New England. Lastly there is the expense of the local grocer for getting the flour and delivering it to the kitchen or to the farmer's car or wagon. The United States Tariff Commission has made a study of the costs of producing flour in this country to find how milling costs in the United States compared with costs in Canada. The Commission found that the average cost for sacks is 36.5 cents per barrel of 196 pounds, and the total selling expense 32.5 cents or a total of 69 cents per barrel. Since the conversion cost was shown to be 65 cents it means that the containers or sacks and the selling expense amount to more than the cost of converting the wheat into flour. In other words, this modern convenience costs more than it does to do the work for which the pioneer paid "toll," or the work which imposed so much drudgery on those people in ancient times who were compelled to do the milling.

It takes four bushels and forty pounds of wheat on the average to produce one barrel of flour. If the cost of this wheat is added to the above items, the actual cost of the flour at the mill is obtained. To this must be added the profit, freight charges and cost of the grocer's service.

CHAPTER X

FOOD CONSTITUENTS OF WHEAT FLOUR

When any food material is analyzed by the chemist the report is usually given in so many per cent of water, protein, starch, sugar, cellulose, fat, and mineral matter or ash. Besides these, foods contain also the vitamins and materials which give flavor; the last two are found in such small amounts that they are not determined in ordinary methods of chemical analysis. The average composition of wheat, flour, and bran as usually determined by the chemist is shown in the following figures:

	Wheat	*Flour*	*Bran*
Water or moisture	12.00	13.50	13.00
Mineral matter or ash	2.00	.40	5.80
Protein or nitrogenous matter	12.00	11.00	15.40
Cellulose or crude fiber	1.80	0.25	9.00
Fat or ether extract	2.00	1.25	3.60
Starch and sugar or carbohydrates	70.20	73.60	53.20
Total	100.00	100.00	100.00

Water or moisture in flour or in any food means that portion which passes off or the per cent that is lost when the material is dried by being kept at a temperature of boiling water or above at conditions which the chemists have found suitable for this determination. Water evaporates from a free water surface at all temperatures, and water is also lost from food substances at all temperatures when the

amount present is above a certain per cent. Thus water is lost from all greens very rapidly. The water will pass off until an equilibrium has been reached and then the weight remains fairly constant. With an increase in relative humidity a small amount of water would again be taken up by the dried food and with a decrease in relative humidity a small amount would be lost. Substances like grains or grain products such as flour and starch have attained an equilibrium. The amount of water in these substances usually varies between 10 and 15 per cent, depending partly on the character of the substance and also upon relative humidity. Flour will lose in weight after leaving the mill if stored in a dry place. Some of this loss may be regained if the relative humidity of the air is increased.

The amount of water in flour is determined by drying a weighed amount for a definite time at a temperature which has been found best for this determination, and after drying, the flour sample is weighed and the loss in weight is figured as the per cent of water. Up until recently the standard method for determining the amount of water in flour was by drying in a so-called "water oven" as the temperature of the drying chamber was regulated by the temperature of boiling water. A number of years ago a large number of flour samples were collected from different parts of the United States and the amount of moisture was determined by this method. The average of all these determinations was very nearly 13.5 per cent, and on this basis the official standard for moisture in flour was placed at this figure.

In recent years chemists have been busy devising more rapid methods for the determination of moisture. They found that they could get results more quickly by drying in a vacuum oven either at the temperature of boiling water or still more rapidly if the drying was done at a considerably higher temperature. Such a procedure gave a higher moisture content than they had obtained by drying in the water oven. This was not due to the fact that the flour contained more water, but simply that the method was more efficient in getting a larger percentage of the water which was present. By a line of reasoning which is outside the scope of this chapter it can be demonstrated that it is impossible to obtain absolutely all the water present in flour or in any other food substance, therefore any moisture determination is relative, and in order to have uniform results it is necessary to have uniform methods. Because of the change in methods the official standard for flour has now been established at 15 per cent when the moisture is determined by the methods which use the higher temperatures or the vacuum.

Water is present in practically all food materials. In fact, it can be said that water is present in traces in the driest food materials. Sugar is one of the driest foods, containing about one-half per cent of water or less. Starch appears to be a dry food, but contains about 15 per cent of water. Fresh bread is about one-third water. Cooked potatoes contain about 75 per cent water. Apples and other fresh fruits have from 85 to 90 per cent. Milk contains on the average 87.5 per cent water. Greens like lettuce are 95 per cent water. As a rule, vegetables have a

very high water content, while cereals in comparison have a low water content.

Foods which contain large amounts of water are difficult to keep in storage. This is the principal reason why it is more difficult to preserve vegetables than cereals. Because cereals contain such a small per cent of water it is possible to keep them in storage without deterioration for considerable periods of time.

One of the important processes that take place when grains ripen is desiccation and this process seems to proceed to a somewhat definite limit which in wheat is reached when the water content is somewhere between 11 and 14 per cent under average harvesting conditions. This seems to be the amount of moisture which wheat may contain if it is to keep well in storage. If the amount of moisture is increased a few per cent above this either in wheat or flour they do not keep well in storage. The temperature is also important. More moisture may safely be present at low than at high temperatures. This is one of the reasons why it is so much more difficult to keep flour in the tropics than in temperate climates.

From the standpoint of energy, water in foods has no more value than water which is taken into the body in liquid form, but water in food has a value in that it adds to the palatability and one of the values of fresh vegetable foods is their succulency. However, in comparing foods from the standpoint of total nutrients present, the amount of water present should be considered. As a general rule, the drier foods contain more total nutrients than foods which contain more water. To illustrate: a 48-pound sack

of flour contains about 41 pounds of total dry substance, while a bushel of raw potatoes weighing 60 pounds contains only from 13 to 15 pounds of dry substance. Thus we see that, in round numbers, a sack of flour contains approximately three times the energy material found in a bushel of potatoes.

Water is one of the most important substances in nutrition. This is easily realized when we consider that the body is approximately two-thirds water, and that water is lost from the body at all times and in various ways. Unless this water is replaced, serious consequences follow. In fact, all animals suffer sooner from lack of water than they do from lack of solid food. However, there is a great difference in different animals in the frequency with which they have to have water. Camels can go a long time without water, because they can store large quantities of water in their bodies. Sheep on the western plains can go for a considerable time without water because they have become accustomed to this by living for a long time in a dry climate. Most domestic animals, as well as man, need to partake of water a number of times a day.

Most of the water needed for the body is taken in liquid form, but large amounts are also obtained in food, particularly when the diet is made up of those foods which contain large amounts of water, such as vegetables or milk. Palatability of foods is closely related to the water content. For example, fresh bread containing 35 per cent water is more palatable than after a considerable part of this water is lost. Fruits as well as other succulent foods owe their palatability in a large part to the water

they contain. One reason why preservation of certain foods by drying is not a success is that palatability, as well as some other desirable factors, are lost in drying.

The mineral matter, or the ash, is the incombustible part of the food. Ash or mineral matter is composed mostly of those elements which the plant takes from the soil. Mineral matter in flour is usually known to the miller as ash. It is determined in flour by burning a weighed amount under specific conditions of temperature and time. In burning, all the organic matter of the flour is consumed and the ash which is left is very small in amount and is light, fluffy, and of a grayish color. The conditions necessary for determining ash in flour are that the temperature shall be such that all combustible materials are consumed, and also that the temperature shall not be so high as to volatilize any of the ash. The ash determinations must be done by a person who is trained to do this work.

The importance of mineral matter in nutrition can be realized when it is considered that the animal body is composed of from 2 to 4 per cent mineral matter. Most of the mineral matter of the body is found in the bones but it is also found to a considerable extent in the other parts of the body, such as the muscles and connective tissue, which contain more than the fat. The mineral matter of the body is made up chiefly of the elements calcium, phosphorus, potassium, sodium and chlorine. Of these, phosphorus and calcium are present in the largest amount as these two are the principal elements in the bone structure. Aside from bone building, the

mineral elements are also necessary for several other body functions. It is absolutely necessary for health and well-being that the foods which comprise the diet contain the essential mineral elements in the right amounts.

As a class of food substances, cereals contain a comparatively small amount of mineral matter. The more refined the cereal foods are, the less amount of mineral matter they contain. The figures presented at the beginning of the chapter show that wheat flour contains only about one-fourth as much mineral matter as the whole wheat kernel. Cereals should not be considered as sufficient sources of mineral matter. Other foods contain these in much larger amounts. Fresh meat free from bone has, on the average, more than twice as much mineral matter as flour. The vegetables as a rule are rich in minerals and hence serve as good sources of the needed elements. Fresh cabbage and potatoes, pound for pound, contain over twice as much mineral matter as flour and in this connection it should be remembered that these vegetables contain from five to six times as much water as flour. On the same dry matter basis they contain about 10 times as much mineral matter as flour.

In adequate nutrition it is not only necessary that the total amount of mineral matter be provided but it is also necessary that the right elements are furnished. One pound of milk with its 87.5 per cent of water contains nearly twice as much mineral matter as one pound of flour, and one pound of dry milk contains about seven times as much. But this is not all. Milk is particularly rich in one very

important element in which wheat flour is poor; namely, calcium. For this reason milk is a very good source of this mineral element which is lacking in flour. The subject of minerals will be referred to again in a later chapter.

Protein, when used in connection with food analysis, includes all the nitrogenous matter. In wheat or flour, protein is estimated by determining the total nitrogen and multiplying by the factor 5.7. Protein is important in flour not only because of its value as a food constituent, but because protein in flour has distinct characteristics unlike those of other grains. It is because of these characteristics that when water is added to flour, dough is formed because the protein of wheat flour combines with water to form gluten. The amount and quality of this gluten determine largely the quality of flour for bread making.

Protein is the most abundant material in muscle and connective tissue, hence protein is the most important food substance for growth and repair; that is, materials which are used by the body to build its tissue and to repair worn-out tissues.

Protein in cereals does not possess the same value in human nutrition as protein from some other sources. The reason for this is that cereal proteins do not contain all the materials in sufficient amounts needed by the body for growth and repair. Cereals can therefore not be relied upon as the sole source of protein, at least for growing animals. They must be supplemented by protein from other sources, particularly those from meat and milk. More will be said on this subject in a later chapter.

There is very little cellulose or fiber in the endosperm of the wheat and hence there is very little in the flour. The cellulose which is present in the flour is mostly from the cell walls of the endosperm. The figures presented at the beginning of the chapter show that the wheat kernel contains about 2 per cent of cellulose or crude fiber and the endosperm only 0.25 per cent. Calculations made on the basis of the relationship between the amount of bran and endosperm in the wheat kernel show that the amount of cellulose in the bran coat is about 9 per cent.

As it is very difficult to determine the absolute amount of pure cellulose in food, the amount obtained by the usual methods of analysis is designated as "crude fiber." The determination is made by boiling for half an hour in 1.25 per cent sulphuric acid, filtering, and washing, and then boiling the residue again in 1.25 per cent sodium hydroxide or alkali, and what is not dissolved is considered crude fiber. This shows that this material is relatively very resistant to chemical reagents. This should not be taken to mean that crude fiber is absolutely indigestible, but it should be taken to mean that the amount digested is very small or that it is difficult to digest.

The amount of fiber in flour is so small that this has very little importance as a food. It seems that same roughage is needed by the body, which may be due in part to the fact that the human body was developed under conditions where it was necessary for man to use large amounts of rather coarse foods. It may also be due to the fact that several of the

vitamins, which are absolutely essential to health, are found in combination with foods which contain a considerable amount of roughage. It should be mentioned here that some nutrition experts are inclined to question the need of the body for roughage. Be that as it may, it is true that vegetable foods which supply needed mineral matter as well as certain vitamins, at the same time supply the roughage. It is better, then, to depend on these foods rather than on food from cereals for the roughage requirements as well as vitamins and mineral matter. Bran contains much more mineral matter than the wheat flour but, as will be shown later, the mineral matter of bran is unbalanced with respect to calcium or lime and this is one of the most needed elements.

The fat from wheat or wheat flour when extracted is in the form of brownish oil, and the amount is very small, only a little over 2 per cent in the whole wheat kernel and about one-half that much in the flour. The wheat germ contains 13.5 per cent fat and hence it is more concentrated here than in either the bran or the endosperm, but as the germ constitutes only about 1.5 per cent of the whole kernel the total amount of fat represented by the germ is not large. The wheat germ would be a good source of human food if it would keep in storage, but up to the present it has not been so used because it easily becomes rancid, especially during warm weather. In the process of manufacturing flour most of the germ goes to the shorts.

Fat is the most concentrated fuel food, one pound giving about 2.2 times as many Calories as one pound

of starch or sugar. Certain plants are particularly valuable because they furnish a large per cent of fat. The competition between animal fat and fat from plant sources is increasing, and more and more of the fat consumed by people will be derived from plant sources. The amount of fat naturally present in wheat flour is of small importance since fat is added as shortening in the baking process and the amount so added is much greater than what was originally present in the flour.

Only a small amount of sugar is found in flour, usually only a few per cent, and this varies considerably. If wheat has been exposed to wet weather conditions which start germination, then the flour contains more sugar than if the wheat has been harvested and kept under conditions where it has remained relatively dry. The amount of sugar in flour is of small importance from the standpoint of total food, as more is usually added in baking than that which is naturally present. However, the amount of sugar naturally present in flour, or the small amount which is produced in the dough during fermentation due to the activity of the diastatic ferments, has an important relation to its baking qualities.

The ingredient which occurs in the largest amount in wheat flour is starch. Both sugar and starch belong to the class of substances known as "carbohydrates" and they are composed of three elements: carbon, hydrogen, and oxygen. If a carbohydrate is heated to the temperature at which an organic material burns or blackens, water is driven off and what is left is similar to charcoal. Starch is one of the

chief ingredients in most foods from plant sources. The chief food ingredient of potatoes is the starch. Beans and peas, which are considered as being rich in protein, contain a large amount of starch; dry beans contain 60 per cent, and dry peas 62 per cent.

As carbohydrates do not contain the element nitrogen nor any of the mineral elements it follows that no animal could subsist on carbohydrates for any length of time. The most important function of carbohydrates in nutrition is to serve as fuel or a source of energy. As flour is made up of nearly three-fourths starch by weight it follows that flour is particularly a fuel or energy food. However, when this is said it should not be forgotten that flour contains about 11 per cent protein and as flour makes up on the average one-third of the total food the amount of protein from flour, as will be shown later, amounts to between 25 and 30 per cent of the total protein requirement.

CHAPTER XI

METHODS OF DETERMINING THE NUTRITIVE VALUE OF FOODS

STUDENTS of nutrition have used a number of methods in order to determine the dietary or the nutritive values of different foods. One method has been to study the dietaries or the amount and kinds of food eaten by different races and different classes of people. Another method has been by chemical analysis of food, or determining the kind and amount of substances a food contains. Another method has been to study the digestibility which is briefly to determine the relation between intake and outgo. Another method has been that of feeding experiments, or what is often called the "biological analysis" of food. These methods have all been useful and each has contributed valuable information.

Chemical Analysis of Food.—As soon as people discovered that the body was composed of the same classes of substances as were present in the foods, it was natural to think that one way of determining food values was by means of chemical analysis. By this method the information contained in the preceding chapter was obtained and by chemical analysis an enormous amount of valuable information has been accumulated. We now know what elements are present in the bodies of animals, and data

are available on the composition of all principal food materials.

Chemical analysis began to be used in attempting to determine the dietary value of different foods as soon as quantitative chemical methods were developed. This study of food values by means of chemical analysis consists chiefly in determining the composition of different foods and comparing their composition with that of the animal body. Chemical analysis may determine the ultimate chemical elements which are present in the food and in the animal body or it may determine the classes of substances such as proteins, starches, sugars, fats and mineral compounds. It was reasoned that since food provides all the substances for building and maintaining the animal body, the food should contain all the necessary substances and constituents for such building and upkeep. Chemists have not only determined the composition of practically all common food materials and compiled tables of such analyses, but they have also determined the comparative energy or fuel value of foods. Bodily heat or energy is maintained by the slow combustion of food materials. The study of the fuel value of foods has shown how much is required to maintain the body under different conditions, and also how much energy may be obtained from different classes and amounts of food.

Chemical analysis has been valuable in pointing out the essential mineral constituents present in different foods. This study has shown that some foods are rich in certain mineral elements that are required by the body and that other foods are very deficient

in these elements. Chemical analysis coupled with other studies has also been valuable in determining the amount of protein required in relation to other classes of foods such as starches, fats and sugars. This study has shown how a diet should be balanced with respect to total protein.

But it is not only necessary to know the total amount of protein in a food, it is also necessary to know the different kinds of protein and their constitution. The protein substance is made up of several units called amino acids and some of these are more essential or valuable than others. Chemists have done a large amount of work to find out the different proteins and amino acids which are required by the animal body and also to determine which of these proteins are present in different foods. This study has contributed a large amount of valuable information. It is now so far advanced that people can know what foods are necessary in the diet in order to provide the kinds of protein or amino acids needed.

A serious shortcoming of purely chemical analysis was that it could not identify vitamins. That certain things besides a balanced ration of protein, fuel foods, and mineral elements were necessary for adequate nutrition was known long before the name of "vitamin" was coined. It was observed that such a balanced ration could be fed to animals and these animals failed to grow or to maintain good health. It was also found out a long time ago in studying the nutrition of different classes of people that those which did not have access to fresh food suffered from certain diseases, and it was noticed that certain races

and peoples suffered from these diseases more than others.

Biological Analysis of Food.—When students of nutrition found that chemical analysis did not gain the results desired, they added the method of biological analysis of food. Essentially this method consists in feeding different food substances to animals and noting the effect. The animals used mostly for this purpose are white rats and mice, guinea pigs, as well as chickens. The selection of the white rat for these experiments was very fortunate, since it happens that this animal is immune to scurvy. The earlier feeding experiments with this animal would have been unsuccessful if these rats had been subject to this disease, but fortunately very many of the most important facts in regard to nutrition were discovered before it was known that the rat was immune to scurvy. This one fact illustrates the importance of not drawing too extensive conclusions from feeding experiments performed with one type of animal. After results have been obtained by using one type it is well to try the experiments with other types and this is usually done.

This method of study has answered a large number of questions in nutrition and now the biological method is very extensively used for the analysis of all kinds of food substances. Results obtained by this method do not make unnecessary the knowledge gained by chemical analysis, the study of fuel values, or of rations balanced in respect to proteins, mineral matter and carbohydrates. All these are fundamental. But the biological method includes in itself the effects on living experimental animals and

from these effects we can reason as to the effects on other animals, including man.

The Calorific or Fuel Value of a Food.—One of the most important functions of food is to maintain bodily heat or energy, hence the fuel or energy value of a food is of the greatest importance. This was referred to in Chapter II in connection with the comparative value of foods. To determine this fuel value a weighed portion of a substance like starch, sugar, fat, or protein is burned in pure oxygen in a closed space. The apparatus is called a bomb calorimeter. The amount of heat produced is measured by the increase in temperature of a certain amount of water. By this method the fuel value of all principal food substances has been accurately measured. One gram of pure protein has a total energy value of 5.6 Calories and one gram of pure carbohydrate has a total energy value of 4.1 Calories. As there are 453 grams in a pound it is simple to compute this on a pound basis. Fat has on the average 2.2 times the fuel value of proteins or carbohydrates.

An enlargement of this study involves the use of an apparatus of such a size that it can contain the whole animal. By means of this the fuel value of food as actually obtained by the animal is measured. The results of these studies have been to establish the net Calorie values of all principal foods. When the animal body burns food material it obtains the same energy value from carbohydrates and fat as is obtained in the bomb calorimeter. From protein it obtains less, or 4.35 Calories per gram. Nutrition students usually estimate as an average four Calories of net energy per gram of protein or

carbohydrates, and nine Calories per gram of fat. If the chemical composition of any food is known it is a simple matter to compute the energy or fuel value. The following are average energy values of typical foods:

Pound of wheat flour...	1610	Calories
" " white bread..	1200	"
" " sugar	1815	"
" " potatoes, white	375	"
" " meat	700-1800	Calories
" " eggs	672	Calories
" " butter	3500	"
" " whole milk ...	314	"

Differences in moisture content and also the amount of fat are the principal reasons for the variation of these calorific values. Starch in potatoes has the same calorific value as starch from wheat flour, but while potatoes contain from 75 to 79 per cent moisture, wheat flour averages about 13.5 per cent. A bushel of potatoes has only from 13 to 15 pounds of dry substance, while a 48-pound sack of flour contains usually 41 pounds of dry substance. The wide range in calorific values of meat is due to the large variation in moisture in fat. Sugar is a pure carbohydrate and has practically no moisture. One pound of butter has approximately the same energy value as two pounds of sugar, but that does not mean that sugar can be substituted in the diet for butter. A certain amount of fat is desirable in the ration in order to provide a sufficiency in Calories. People who live in cold climates or people who work outdoors in severe weather need large amounts of fat in order to supply the energy requirements.

Dietary Standards.—By combining statistical with chemical methods, students of nutrition have established what are known as dietary standards. These standards simply attempt to indicate the total amount of protein and the total fuel value of food needed by persons in different occupations. A certain amount of protein is needed to build the body and keep it in repair, then there must be enough of fat and carbohydrates in addition to give the needed energy value. The following are examples of standards for the classes of people mentioned:

	Protein (grams)	*Fuel Value (Calories)*
Farmers and mechanics	100	3425
Business men, students	106	3285
Very poor people usually without work	69	2100
Women at moderate muscular work	100	2700
Women at light muscular work	90	2400
Children 1- 2 years (av.)	28	765
Children 2- 6 years (av.)	55	1420
Children 6-12 years (av.)	75	2040

People who do very light work and old people need less than those in active work. On the basis of these figures as well as several other facts it is assumed that the average daily calorific requirement of men is 3,000 and of women 2,400, as was stated in Chapter II. It was also stated in Chapter II that on the assumption that about one-fifth of the total population is below 15 years of age it is estimated that the probable per capita requirement for the entire population will not exceed 2,000 Calories per day.

There is probably less agreement among students of nutrition on dietary standards than on almost any other subject. There are so many factors which enter in. One fact should be noted: With an in-

crease of Calories there need not be a corresponding increase in protein. That is, a man who does hard muscular labor and needs a larger number of Calories does not need a correspondingly large amount of protein.

The tendency in late years has been to reduce the amount of protein in the standards. Some estimate that a diet which furnishes 3,000 Calories need contain only 75 grams of protein. Then the kind of protein enters into the problem. Protein from cereals would not have the same value as protein from meat or milk. Then it must be remembered that mineral elements and vitamins are necessary to an adequate diet. At the best a standard is only "an indication, not a rule." For a fuller discussion of this subject the reader should consult works devoted particularly to nutrition.

The Digestibility of Food.—Before food can be utilized by the body it must be digested and hence digestibility is a measure of food values. The following is an illustration of some of the conditions necessary for digestion. If grated or finely divided white of a hard-boiled egg be placed in small portions in three tumblers and stirred up in water, it will be found that this material is not soluble, but will give a white suspension. Then if to tumbler No. 1 be added pepsin and a few drops of dilute hydrochloric acid, to tumbler No. 2 only a few drops of the hydrochloric acid, and to tumbler No. 3 only the pepsin; and further if all three tumblers be kept in a closed place warmed to 100-120° F., the following will be noticed after an hour or more: The contents of tumbler No. 1 will be dissolved, that is,

the solution appears to be clear, but very little or no change can be seen in the other two tumblers. This shows that for digestion in the stomach there should be present water, hydrochloric acid and the digestive ferment known as pepsin. This illustrates that digestion will not take place readily unless all the conditions are fulfilled. Very often sickness is due to the failure of some digestive function.

As soon as food is taken into the mouth digestion begins. Any one knows that prolonged chewing of bread makes it taste sweet because the saliva has a digestive ferment which can change the starch to sugar. In the stomach there are digestive ferments and in the intestines there are still others which in turn act on proteins, fats, and starch or other carbohydrates. The work of digestion is to break down the food compounds into simple substances which can be absorbed into the body fluids, and transported to various parts of the body where they are utilized. For instance, the protein found in flour or meat is a very complex substance. The digestive ferments break down this protein into simpler ones and the simpler units are then used to build the body structure or to repair worn-out parts.

The completeness with which food substances can be broken down and utilized measures the digestibility of a food. This is learned by determining the balance between income and outgo from the body. If the percentage of digestibility of a food is 85 per cent it means that 15 per cent of the food passes through the body essentially unchanged, while 85 per cent is utilized.

The method which has been used most for determining digestibility is that of natural digestion. The simplest form of this method is to determine the total intake of all chemical compounds present in the food and the total outgo of the same compounds. The difference between these two quantities is considered to be the digested portion and from this the percentage of digestibility is computed.

Another method of determining the digestibility of a food is by artificial digestion, which is done by adding the digestive ferments or enzymes to a food kept under specified conditions of temperature for a given length of time. These enzymes are the same as those found in the digestive juices and they dissolve the food and the amount of food so dissolved in a given length of time measures the digestibility.

Factors Which Influence Digestibility

There are certain factors which influence the digestibility and one of the most important factors is that of physical condition. For instance, the digestibility of a protein in certain vegetable foods is different from that in certain animal foods, one probable reason being that in such vegetable substances the protein occurs in combination with large quantities of other material, particularly fibrous matter. If this fibrous material envelops the protein, then the digestibility is less than if such fibrous material is absent. For this reason proteins in animal foods as a class are more digestible than proteins from grains, and in turn the proteins from grains are more digestible than the proteins from vegetables.

The comparative digestibility of proteins, carbo-

hydrates and fats can be seen from the following figures of percentage digestibility:

	Proteins	*Carbo-hydrates*	*Fats*
Meats	97		95
Dairy products ..	97	98	95
Cereals	85	98	90
Mixed diet	92	98	95

In this connection it is important to note that the percentage of digestibility does not tell the whole story. This percentage simply signifies the completeness of solution by the digestive juices and the absorption of the food. It does not tell anything about the rate or the ease of digestion. Some foods under certain conditions may be as completely digested as other foods, but at a much slower rate. A food that digests slower may be less valuable under some conditions than another food that digests more rapidly. Certain foods may have a high percentage of digestibility, but they may produce discomforts with some people. The popular statement is that such foods do not "agree," and this is not told by the figures for digestibility.

The flavor and appearance are important. The sight and taste of palatable food excites the flow of digestive juices. The mouth "waters," according to a familiar expression. White, light bread is more pleasing to most people than dark, heavy bread, and this is an important factor in nutrition.

The physical condition of white, light bread is one of its most distinctive characteristics. When water is added to wheat flour, gluten is formed. The protein or gluten particles adhere to each other in such

a way as to form strings or strands. These strands when wetted with water and when enmeshed with starch form membranes. The dough is a mass of such membranes, and when yeast grows in the dough, it becomes permeated with cells having very thin walls. When such dough is baked, these cells are "set," and the baked bread consists of a mass of very thin, flimsy cell walls. The thinness of these cell walls is a condition favorable for the optimum action of the digestive juices. For this reason light, white bread is a food more universally liked by people than any other one article.

CHAPTER XII

REQUIREMENTS OF A DIET

WITH a large number of people appetite or liking for certain foods is the measure of food values, but students of human nutrition have found that this is not a reliable guide for the simple reason that appetite is to a certain extent a matter of habit and can be trained. Sometimes people acquire a dislike, which may have no real basis whatever, for a good wholesome food because of something they have heard or seen. The serious part of such a dislike is that it may deprive them of a food which supplies some substance absolutely essential to health.

We must eat to live, but if we are to really live and have abundant life we must eat properly, and thereby goes a story. The human body may be likened to an automatic machine, but such a machine is useful only if it has power and abundant power. We all admire the smooth-running engine, and we have faith in the engine which has reserve power.

The human body is more than a machine in that it is self-repairing and self-building. It starts from a very small microscopic cell and grows gradually into the full stature of manhood or womanhood. Similar to all machines, parts wear out and the worn parts must be repaired. The body is a delicate

organism made of bones, muscles, fat, as well as other tissues and fluids. To keep it going it must have air, water, and food. Food is the source of the material used for growth and repair. Without food of the right kind and in proper amounts a normal healthy body will not grow and without such food it will not be maintained in good working condition after full stature has been attained.

Four Fundamental Requirements of a Successful Diet

In general it may be said that any diet in order to be adequate or successful must fulfill the following four fundamental requirements:

1. The diet must furnish material for growth as well as repair. To do this the diet must contain an adequate amount of such proteins as furnish the necessary amino acids, and also mineral matter or ash, particularly calcium and phosphorus. Proteins from animal sources, such as milk, eggs, and meat are of particular value in balancing the proteins from cereals, and proteins from legumes such as peas, beans, soybeans are also valuable. It is possible to make a biologically balanced diet entirely from plant materials; that is, a ration which furnishes material for the adequate repair of the mature animal as well as growth of the young, but whether this is desirable or not is another question.

2. The diet must furnish sufficient fuel material, since to keep the body active and working requires a large amount of energy. Such fuel foods are the carbohydrates and fats; starch, sugar, and syrup represent carbohydrates; and butter, lard, vegetable

oil, and margarine are representative fats. It was shown in Chapter XI that one gram of protein furnishes as many calories as one gram of carbohydrate. Protein is therefore a fuel food as well, but its primary function is to furnish material for growth and repair.

3. The diet should give the body such vigor that it has a high degree of resistance against disease. It is known that a number of diseases result from dietary deficiencies. The deficiency may be in that the diet does not furnish certain substances needed by the body, to maintain it in that state of vigor in which it has a high degree of resistance. There is nothing mysterious about such deficiencies. We know that the body must have a constant supply of air. Lack of air is shown in failure of the nerves to function and the body faints. The body must have a constant supply of water. Lack of water manifests itself first as thirst, and if there is a continued lack of water more serious consequences will follow and finally death. Lack of proteins or mineral elements would mean lack of material for growth and repair. Lack of fuel food would mean that the body would burn its own tissues. The most important elements in the diet for protection are the vitamins, and foods which furnish vitamins are called protective foods by some nutrition experts.

4. The diet must also maintain what may be called reproductive health and provide nourishment for the young. The failure of mothers to nourish the young adequately and to maintain them in good health is due in many cases to a deficient diet, not only during gestation but also during lactation. The

foundation for the permanent teeth begins to be laid at the 25th week of gestation. Future dental troubles can be traced to conditions existing before birth and during the first two years of life.

Importance of Mineral Matter

Students of nutrition realized many years ago that it was possible to have a diet well balanced with respect to protein in relation to total carbohydrates and one which had a sufficiency of Calories and still not be well fed. A balanced ration in this sense is one which contains an adequate amount of total protein in relation to the total fuel foods, such as fats and carbohydrates. A serious lack in such a ration may be the insufficiency of mineral matter or the noncombustible portion of the food; another deficiency may be the vitamins which will be discussed in Chapter XIV. It has long been recognized that the diet must contain materials for building and repairing bone and the mineral matter is also exceedingly important in maintaining certain other functions of the body in a healthy condition. Nervousness is in many cases due to an unbalanced mineral condition. An enormous amount of study has been expended on the mineral requirements of the body and it is well established that certain mineral elements are just as essential in the diet as protein, fats, carbohydrates, or even the vitamins. However, it is not only necessary that the mineral elements must be present in the food, they must also be utilized. Often a sufficiency of the right kind of elements may be furnished in the diet, but the body is unable to make use of them because of the

lack of certain vitamins. This is particularly true of calcium.

When wheat or any seed is burned under carefully controlled conditions, there remains a small amount of gray material which is called ash. From wheat there is obtained on the average 2 per cent ash, and from white flour about one-fifth as much. Because there is five times as much mineral matter in whole wheat as in white flour and because the body needs mineral matter some people have reasoned that nature intended that the whole kernel should be consumed and that the removal of the bran meant that some of the best parts of the wheat were removed in the milling process. These reasons or arguments have sometimes gone to the absurd length of stating that white flour contains practically nothing but starch, and that flour is devitalized food, and also because the miller removes part of the wheat essential to nutrition he is committing a wrong. To understand adequately this situation it is necessary to take several facts into consideration.

Elementary Composition of Human Body

Chemical analysis has shown that the body is made up of chemical elements. Some of these elements are found in water, others in the soil, and still others in the plants. These chemical elements are combined to make such well-known substances as water, proteins, carbohydrates, fats, as well as compounds of mineral matter such as phosphates, chlorides, carbonates and others. The following figures give the average percentage of elements found in the human body.

Elements	*Per Cent*	*Elements*	*Per Cent*
Oxygen	65.0	Sulphur	0.25
Carbon	18.0	Sodium	0.15
Hydrogen	10.0	Chlorine	0.15
Nitrogen	3.0	Magnesium ..	0.05
Calcium	2.0	Iron	0.004
Phosphorus ...	1.0	Iodine	trace
Potassium	0.35	Fluorine	trace
		Silicon	trace

The large proportions of oxygen and hydrogen are due to the fact that approximately two-thirds of the body is water and also that these elements are present in other compounds as well, such as proteins, carbohydrates and fats. Nitrogen occurs in relatively small amounts when we consider that this is the distinctive element in protein which makes up a large part of the muscles. Of the so-called mineral elements, calcium and phosphorus occur in large amounts because they are used so largely as building material for the skeleton. While such an element as iodine occurs only in traces it illustrates the importance of these elements which occur in very small amounts. It is now known that absence of iodine from the water or from food is the most common cause of simple goiter. These figures on the composition of the body show without further argument that the body must have certain mineral elements just as much as it must have the elements which compose water, fats, or proteins, and any diet which lacks these mineral elements must be classed as deficient. The question is not the need of these elements, but what foods furnish the best supply.

Mineral Elements in Wheat and Wheat Products

Professor E. B. Forbes and associates report the following percentage of ash or mineral elements in wheat and wheat products. (Ohio Experimental Station Bulletin No. 255.)

	Wheat	*Wheat Flour*	*Wheat Bran*	*Wheat Shorts*	*Wheat Germ*
Potassium .	.520	.050	1.320	1.021	.296
Sodium ...	.031	.110	.201	.165	.721
Calcium ...	.050	.019	.125	.096	.071
Magnesium.	.130	.016	.531	.383	.340
Sulphur ...	.198	.145	.267	.234	.325
Chlorine ..	.084	.070	.090	.025	.070
Phosphorus.	.373	.088	1.110	.876	1.050

All of the mineral elements in wheat are also present in the human body, but if the figures for the composition of the body are compared with the figures for the composition of mineral matter in wheat and wheat products it is at once apparent that certain elements which occur in large amounts in the body occur in relatively small amounts in wheat and wheat products. To illustrate: There are 2 per cent of calcium in the body and 0.05 per cent in the whole wheat, and less than half that amount in white flour. The body would not get a sufficiency of calcium even if whole wheat was used instead of flour. This simply means that food material poor in calcium, such as white flour, cannot be supplemented by other materials, such as whole wheat or bran, which is poor in the same element.

A pound of milk contains six times as much calcium or lime as a pound of wheat flour. Practically all garden vegetables, especially those which have

thin leaves, are rich in lime as well as the other needed mineral elements. Cabbage, potatoes, carrots, and green peas contain as purchased about one per cent mineral matter; lettuce and green beans nearly one per cent, hence pound for pound they contain twice as much mineral matter as flour. But this is on the basis of a water content of 70 to 90 per cent. On the basis of the same amount of dry material as flour these vegetables contain from 10 to 12 times as much mineral matter.

Importance of the Protein

Students of nutrition have recognized for a long time that some foods furnish proteins that were much better adapted to the needs of the human body than proteins from other foods, and it was also recognized that it was possible to have a sufficient amount of protein and yet not have material for adequate growth and repair. Proteins from milk and eggs were found to have a value in supplementing proteins from plants beyond what would be expected on the basis of quantity. Thus a comparatively small amount of milk protein sometimes makes an enormous difference in the rate of growth of a young animal, and this cannot be accounted for on the basis of quantity of protein. Proteins from milk and eggs have always occupied a high place in nutrition. These are followed by meat proteins, and proteins from cereals would probably take third place. Why are proteins from some sources better nutritionally than from other sources?

When the chemist determines protein he simply finds out how much total nitrogen is present and

then he multiplies this by a factor and calls the result per cent of total protein, but this does not tell us the relative nutritive value of protein from different sources. Chemists have found that the total protein so determined is composed of several individual protein substances. Thus flour protein is composed of gliadin, glutenin, edestin, leucosin and proteose. Gluten is composed principally of gliadin and glutenin. In milk are found the proteins albumin and casein. One of the principal proteins in corn is zein. As soon as it was recognized that protein from different sources had different nutritive value, students of nutrition isolated these proteins and fed them to small experimental animals. This gave valuable information, but the protein problem was still enveloped in a great deal of uncertainty.

The next step was to determine the composition of these individual proteins. By the use of chemical reagents it was found that these individual proteins could be broken down into a number of simpler units called amino acids. It was found that most of these amino acids were found in the different proteins, such as were mentioned in the last paragraph, but they were in different proportions, and not all amino acids were found in every protein. Some amino acids were present in some proteins and not in others. The following figures serve to illustrate this point and they show the percentage amount of amino acids present in five well-known proteins: myosin from beef, casein from milk, zein from corn, and gliadin and glutenin from wheat flour.

Amino Acids Found in Some Well-Known Proteins

(Sherman, "Chemistry of Food & Nutrition," pp. 72, 73)

	Beef Proteins	*Casein (milk)*	*Zein (corn)*	*Gliadin (wheat)*	*Glutenin (wheat)*
Glycine	2.06	.45	0.00	0.00	0.89
Alanine	3.72	1.85	13.39	2.00	4.65
Valine	0.81	7.93	1.88	3.34	0.24
Leucine	11.65	9.70	19.55	6.62	5.95
Proline	5.82	7.63	9.04	13.22	4.23
Phenylalanine .	3.15	3.88	6.55	2.35	1.97
Aspartic acid..	4.51	4.10	1.80	0.58	0.91
Glumatic acid.	15.49	21.77	26.17	43.66	23.42
Serine	?	0.50	1.02	0.13	0.74
Tyrosine	2.20	6.50	3.55	3.50	4.50
Cystine	1.55	0.50	0.85	2.32	1.80
Histidine	1.76	2.84	0.82	3.35	1.76
Arginine	7.47	3.81	1.82	3.14	4.72
Lysine	7.59	7.62	0.00	0.92	1.92
Ammonia	1.07	1.61	3.64	5.22	4.01
Tryptophane .	1.25	2.20	0.00	1.14	present

These amino acids are the individual units of which the proteins are made. When protein food is digested the protein is resolved into the different amino acids. The proteins of the body contain the same amino acids as are found in the food. Growth consists in building body protein from the amino acids obtained from the food, and repair of body proteins means that the worn-out parts are replaced by proteins built from the amino acids of the food. From this it follows that the right amino acids must be present in the proteins of the food if the needs of the body shall be satisfied. By comparing the amount of the different amino acids found in meats, milk, eggs, with those found in flour it is apparent that certain ones which are present in very small amounts in flour are present in large amounts in

the animal foods. This condition furnishes the fundamental basis for balancing proteins from different sources.

It should be emphasized that not all of the amino acids are present in every protein. It is also a fact that some of these amino acids which are absent in some proteins are absolutely necessary for nutrition. Feeding experiments with small animals have shown that lysine is absolutely necessary for growth and that tryptophane is absolutely necessary to maintain life. Lysine occurs in comparatively large amounts in myosin of beef and casein from milk, but is absent in zein from corn, and is present in small amounts in the two wheat proteins, gliadin and glutenin. Casein is a good source of tryptophane.

Crude protein as usually determined by the chemist means a mixture of several individual protiens, and some of these contain only very small amounts of the amino acids essential for life. Therefore, if such proteins constitute the greater part of the crude protein, it means that the total food must contain a much larger amount of crude protein. To illustrate: All whole seeds which have been studied are known to contain every amino acid necessary for life's functions, but some seeds contain certain essential amino acids in very small amounts. As shown by the figures in the above table, gliadin contains only a very small amount of lysine, so small indeed that if this is the sole source of lysine, the animal would not grow. As a matter of fact, practically all cereal seeds contain only small per cents of lysine. If seeds are the sole source of food for growing animals, the growth will be slow because of the

small amount of lysine furnished. As casein has a large per cent of this amino acid milk is a very good supplementary food for growing animals.

It follows, therefore, that what must be provided in the diet is not merely protein, but protein supplying the needed amino acids. These will usually be furnished if a mixture of proteins both from animal and plant sources is fed. Milk and meat are foods which supplement the proteins of wheat, and they do this because those amino acids which occur in small amounts in the proteins of grains occur in large amounts in casein and myosin. Hence milk, meat, and eggs are excellent supplements to white bread.

Successful Types of Diet

Three types of diet which have successfully met the requirements pointed out in the earlier part of this chapter have been described by Dr. E. V. McCollum. It is not expected that the people under conditions of modern civilization can practice any one of these types. These facts are presented to show that diets may differ greatly in certain respects and if they contain the essentials of an adequate diet, the body will be maintained in good health. These types are the carnivorous, the vegetarian, and the milk diet, and these have been and are used at times by various peoples in different parts of the world.

1. The carnivorous is an all-animal diet, but the food is not what civilized people usually class as meat. Muscle meat is as deficient a food in some respects as wheat flour, whose deficiencies have been widely proclaimed. A real carnivorous diet is one in which all the animal tissues are eaten. The neces-

sity of consuming all the tissues of an animal is particularly noticeable in the feeding of carnivorous animals. For a long time it was impossible to rear the young of carnivorous animals in captivity. Even if the cubs of lions and tigers did survive they were so deformed from rickets as to be unfit for exhibition purposes. The practice was to feed the mothers of the cubs with muscle meat with some bone included. This was thought to furnish all that was necessary for the mother, but the fact that she could not rear healthy, normal young proved the deficiency of the diet. Since the science of nutrition has advanced to its present state, it is now possible to rear these cubs in captivity and produce vigorous animals, but this has been done only by feeding the entire bodies of other animals, particularly such animals which either themselves live on a vegetable diet or consume other animals which live on a vegetable diet. Primitive people who subsist on a carnivorous diet made it a practice to include all the glandular organs as well as the muscle and fat.

2. The second type of diet which has succeeded is the vegetarian in which leafy vegetables form a large part of the food. This vegetarian diet has been successful in certain parts of the Orient and it has maintained people in vigorous health even where they had to live under congested conditions, but such a diet includes an abundance of green vegetables. A vegetarian diet which consists mostly of grain will not be successful.

3. The third type of diet which has succeeded is the one which includes large amounts of milk. This has been used particularly by people who live under

pastoral conditions. The food of these people consists largely of meat, but at the same time it includes milk.

While civilized people cannot adopt any of these types to the exclusion of other types, yet the food must contain what is essential in either the carnivorous, the vegetarian or the milk diet. The reason that these diets are successful is that the necessary vitamins are furnished as well as balanced proteins, adequate mineral matter, fats and carbohydrates, and no diet can be considered successful unless it contains these essentials.

CHAPTER XIII

SOME EFFECTS OF DEFICIENCIES IN THE DIET

It has been long known that people who subsist on certain classes of diet are likely to suffer from certain diseases. Sailors who formerly went on long voyages and hence lacked fresh food suffered from scurvy. People who subsist on polished rice suffer from beri-beri. Rickets is a disease which manifests itself as a mineral deficiency of the bones and is likely to be found among children not properly fed. These diseases cannot be accounted for on the basis of a ration unbalanced with respect to the relation of the amount of protein to other foods, which means they cannot be prevented or cured by a ration which contains the right amount and kind of proteins and a sufficiency of mineral matter. It is very evident that there must be some other things necessary for an adequate diet. These are the vitamins. In this chapter we will consider some of the diseases or disorders which may be caused by a deficient diet. In Chapter XIV the vitamins will be considered in relation to a diet which will prevent these diseases.

It is possible to have a diet or ration which meets all the requirements from the standpoint of chemical analysis, one which has a high degree of digestibility, and one that is in accordance with certain dietary

standards; that is, it is possible to have the proper kind and amount and the correct proportion of protein in relation to fats and carbohydrates such as sugar and starch, and yet have a deficient diet. If this is so, what is the use of chemical analysis, digestibility studies and studies to establish standards for different classes of people? The answer is simply that these are all fundamental, since if a food does not have the chemical constituents needed by the body it cannot meet its requirements. If a food has all the needed chemical constituents, but does not have them in such a form as to be readily digested by the human system, it is faulty. Besides, we must have enough food. It may be true that many people eat too much, but, at the same time, many eat too little. Standards established by careful nutrition studies are a guide to both the underfed and the overfed if followed with judgment and care.

While different deficiency diseases manifest themselves in various ways, the chief characteristic is that they attack the nervous system. The disease known as "beri-beri" is common among people of the Far East who subsist largely on polished rice. This disease manifests itself in swelling of joints and deterioration of muscles, and if not cured it is fatal. One of the first discoveries made in the study of the causes of this disease was that if rice was not polished the disease would not occur, or if the rice polish was added to the diet beri-beri could be cured.

Another disease due to deficiencies in the diet is known as pellagra, and usually occurs among people who eat a large amount of corn or refined cereal

foods. This disease manifests itself in a rough skin and general impairment of the nutrition of the nervous system. It was thought for a long time that corn contained some deleterious substance which caused this disease, but this has not been substantiated. It has been found that the best remedy for this disease is to have a variety of diet, especially one that includes lean meat, milk, eggs, and fresh vegetables.

One of the oldest known of dietary diseases is scurvy. This disease, its cause and cure, was recognized long before the modern science of nutrition. This disease manifests itself among other symptoms, in the loss of power in the limbs, swelling of muscles and weakening of joints. It was very common among sailors who went on long voyages and lacked fresh food. When humans are afflicted with scurvy the bones become brittle, the gums are affected and the teeth loosen and fall out. If this disease is not cured, paralysis and death follow. Active scurvy is not common among the adults in the ordinary walks of life but students of nutrition, however, are of the opinion that mild scurvy is rather common among grown people. It is more common among infants in the poorer sections of the large cities. It was discovered a long time ago that if the juice of citrous fruits was included in the diet, scurvy would not appear.

Rickets is another dietary disease which has been known for a long time. This disease manifests itself as a deficiency of mineral matter in bones. It was observed a long time ago that this disease does not occur among wild animals living in their native

habitat, but it does occur when it is attempted to raise wild animals in captivity in the absence of sunlight, and it is only recently that the conditions for raising such animals have been known.

Rickets is a disease brought about by faulty nutrition, and is most common in young children. Symptoms of rickets are restlessness, irritability and constipation. Some students of nutrition estimate that about half the children of the United States suffer from rickets in some form. It is said to be most common in children under two years old. In advanced stages it shows itself in bony deformities. Teeth decay is a form of rickets. Muscles become lax, the bones which should be hard and strong become soft and weak. The teeth do not develop properly. Because of softening of the bones, the children do not stand or walk as they should. As the disease advances, deformities begin to appear in bone growth, such as enlargement of wrists and ankles, knock-knees or bowlegs, "chicken breast" and curvature of the spine.

While rickets may be fatal in itself, if death results it is usually from some complication. It makes the children susceptible to other diseases because of lowered resistance. Children who have rickets suffer much from colds and bronchitis. Often death results from pneumonia.

Xerophthalmia is another deficiency disease which manifests itself as an inflammation of the eye. The eye assumes a state of dryness and then becomes inflamed. The inflammation is due to the presence of disease germs which have gained ascendancy because of lack of resistance. This will happen when

the diet does not contain certain foods carrying vitamin A. This vitamin will be discussed in the chapter on vitamins. It has been well established by nutrition students that certain diets or combinations of foods do not maintain the body in health and vigor, and that other combinations of food in the diet prevent the above diseases and even effect a cure if the ravages have not gone too far. However, nutritional disorders may not go as far as would be indicated by the above-mentioned symptoms. A common manifestation of nutritional disorders is weaknesses which mean impairment for work. This may go far enough to bring on a functional disease, or it may be the indirect cause of a bacterial disease, due to lessened resistance.

In the minds of some people these substances which are lacking in the diet and which would protect the body against disease are enshrouded in more or less mystery and uncertainty, but there need be no more mystery about these than about some of the most common phenomena of life. The lack of air will cause physiological disturbances and if air is kept away for a short time death will follow. We may say that lack of air would develop a deficiency disease. Animals differ, however, in the amount of air needed. Fish can get all the oxygen they need from that which is dissolved in water, while mammals would die quickly if they were confined to this amount of air. Certain insects can live under conditions of very little air, while others must have free access to air. Lack of water will develop serious physiological distress, and hence it may be said that lack of water is the cause of a deficiency

disease. Animals differ, however, in the amount of water required. Horses must have water several times a day, while camels can go several days without water after they have been filled. Sheep can go much longer without water than cattle.

Attention has already been called to the fact that the body needs sugar and starch as fuel foods. Fats are needed for the same purpose. There is a difference, however, in the amount of these substances needed by different people. People who live in very cold climates have a craving for fats which is due to the fact that the body needs food that will produce a large amount of heat, and fat supplies this in a smaller bulk than any other food. Animals which live in a wild condition store fat in the fall in order to be able to resist the cold weather.

All animals need protein, fats, carbohydrates, mineral matter and vitamins. We may say that no particular kind of food is needed, provided it supplies the protein which contains the required amino acids; the power foods which are found in the carbohydrates and fats; the mineral salts, particularly those of calcium and phosphorus as well as others which are necessary to regulate the reaction of the body fluids. The food must also contain certain substances which are called vitamins. These will be treated in Chapter XIV. It does not make so much difference whether the foods are obtained mostly from plants or animal sources, provided that they contain the necessary substances. It is for this reason that people have found it possible to maintain good health and vigor on several kinds of diet.

Much has been said about the lack of amino acids

in cereals. Every seed studied by dietary students has been found to contain every amino acid necessary for the animal body, but it has also been found that some of these amino acids are usually present in very limited amounts. Hence if an animal is required to subsist on certain seed it will grow very slowly, if at all. In one experiment with hogs at the Kansas Agricultural Experiment Station it was found that where the exclusive ration was corn the animals grew very slowly for the first two years, but during the third year increase in weight was very rapid. This means that after the first two years a sufficiency of those amino acids and mineral elements which were necessary for building of body tissue had been stored in the body. It was also found in experiments with hogs that if they were put on an exclusive corn ration before they had obtained a certain weight of about 50 pounds they would not grow at all and some of them died. One reason for this is the lack or insufficiency of amino acids in corn. The most abundant protein in corn is zein, but this protein lacks the amino acids lysine and trypotophane, both of which are necessary for adequate nutrition. The other proteins in the corn kernel do contain these particular amino acids in small amounts, but the amounts are so small that whole corn alone does not form a satisfactory ration for growing animals.

The following fact should be carefully noted. The proteins of cereal grains do not supplement each other. It may be said that as a rule all cereal grains are deficient in that they do not contain enough of certain amino acids required. The proteins of cereal grains are best supplemented by proteins from

animal foods or from plant foods which are not classed as cereals. If an animal is confined to plant substances as the sole source of protein, the protein supply must in general be more liberal in the diet than if part or most of the protein comes from animal foods. Among animal foods the proteins of meat and milk have been found to be well suited to supplement the proteins from cereals.

The insufficiency of muscle meat alone has been discussed. There are also some animal proteins, such as gelatin, which are deficient. No matter how much of such a protein is fed, it will not supply the needs of the body. The reason is simply that gelatin does not contain certain essential amino acids. This does not mean that a satisfactory diet cannot be made up with proteins, either from animal foods or from plant foods alone. There are people who are living in good health on a purely vegetable diet, and others who live on a diet of animal foods.

CHAPTER XIV

VITAMINS: MEANING AND IMPORTANCE

VITAMINS have received so much attention in the last few years by some people interested in nutrition that the other requirements of the diet have been somewhat obscured. There is no question about the importance of vitamins or that their absence from the diet leads to serious consequences. But adequate protein, adequate fuel value of food, a sufficiency of mineral matter are just as essential as vitamins. Vitamins were not known until comparatively recently; also since they were absolutely essential, many questions in nutrition remained unsolved until the functions of vitamins were known. Vitamins are absolutely necessary, but not more so than are other food factors. A successful diet must have protein for growth and maintenance, fats and carbohydrates for energy, mineral matter for bone structure as well as other needs of the body, and vitamins for proper functioning of the body as a whole.

Vitamins were first found in rice polish. It was observed that the material from rice polish would cure beri-beri. This disease is very common in the Orient where the diet consists largely of polished rice. The curative substance was crystallized from

rice polish in 1912 and the word "vitamin" was used then by Funk for the first time. Almost an unweighable amount of this substance would cure a pigeon which had lost control of its legs and wings and the cure was effected in two or three hours.

The chemical structure of vitamins is not known in the same sense as we know the chemical structure of proteins, carbohydrates and fats. Some attempts have been made at isolating vitamins in pure form and also making them synthetically. At the present time the best sources of vitamins are well-known food substances. As one of the functions of vitamins is to protect the body against certain diseases, foods which are good sources of vitamins are sometimes called protective foods. To maintain health, such protective foods should always be used in adequate amounts. There have been several ways of designating vitamins, but at the present time the usual way is to name them by the letters of the alphabet. Thus we have the vitamins A, B, C, D, and E, respectively.

Vitamins are little things, but like many other little things they are extremely important and precious. They are just as important as air, water, proteins, fats, carbohydrates or mineral matter. The lack of a vitamin is not made apparent as soon as the lack of air, water, or some of the other food principles. The development of the animal body has taken place under conditions where air and water were always at hand, but vitamins were not always present in the food. For this reason the body has acquired the habit of storing vitamins. An animal which has subsisted on an adequate diet

could live for some days without protein, fats or carbohydrates, for a number of hours without water, but only a few minutes without air. Such an animal may possibly live for a month before the lack of any certain vitamin becomes apparent, because vitamins are stored in the body. This means that it is not necessary to have a plentiful supply of all the vitamins at every meal nor in fact every day, but it does mean that the body must receive an adequate supply in the diet as a whole. The continued lack of vitamins manifests itself in nervous disorders, lack of resistance to disease as well as certain serious diseases, such as have been described in Chapter XIII.

Vitamin A

Vitamin A is essential not only for growth, but also for health at all ages. In order to keep the body in the best condition of nutrition and up to its maximum of vigor and effiicency much more of vitamin A is required than is needed simply for support of normal growth. Lack of vitamin A manifests itself in infected eyes of children and roup of chickens, night-blindness and other complications. Denmark has long been famous for its good butter, but this good butter was exported. Children were fed largely on oatmeal gruel, boiled skim milk and barley soup. The result was serious eye trouble among the children. A law was passed requiring butter in the diet of the children and the trouble disappeared. In Roumania during the World War there was a serious outbreak of eye diseases among the children. The Austrians had driven off all the dairy cows, and the

diet of the children was corn meal and soup from bran and vegetables. Through the aid of the Red Cross a shipload of cod-liver oil was secured and distributed, with the result that the disease disappeared. Cod-liver oil is very rich in vitamin A as well as vitamin D.

Lack of vitamin A also gives rise to other diseases such as kidney disorders, skin diseases, diarrhea, and diminished appetite. One of the most serious results of lack of vitamin A is lowered resistance to bacterial infection, hence lack of vitamin A indirectly causes bronchitis, pneumonia and tuberculosis. In an experiment at the Kansas State Agricultural College twenty hogs were fed on a ration low in vitamin A. Nearly all died from lung trouble, and before death they became blind and paralyzed. Vitamin A is very unevenly distributed among food materials, hence a very high value must be assigned to those foods which are rich in vitamin A. If the body receives more than it absolutely needs for the support of growth and for prevention of deficiency diseases, a reserve is stored in the tissues and this constitutes a very valuable nutritional asset, which gives bodily vigor, endurance and resistance.

Vitamin A is made in nature wherever plants are growing in sunlight so that a green color is developed. As far as known at the present time it is not made under any other condition. This means that vitamin A must ultimately be obtained from plant sources. In the natural plant it is stored in those parts which retain the green or the yellow color. The best sources of vitamin A among animal foods are butter, whole milk, egg yolk, kidney, and

liver. All green leaves contain vitamin A, and among those which are palatable for human consumption may be mentioned spinach, green lettuce, chard, celery leaves, turnip tops, beet tops, radish tops, dandelion greens and outer leaves of cabbage. Yellow pigmented roots such as carrots and sweet potatoes contain vitamin A in larger amounts than white potatoes, white turnips, parsnips, red beets and radishes. Yellow corn contains vitamin A while it is absent from white corn. It is not found in appreciable amounts in vegetable fats such as cotton-seed oil, olive oil, coconut oil, peanut oil. Vitamin A is found sparingly in lean meat and such animal fats as lard and tallow. Whole milk contains on the average several times as much vitamin A as separated milk and since vitamin A is fat soluble, most of it is found in the cream.

Whether vitamin A shall be present in animal foods depends on the feed given the animals. Whole milk normally contains vitamin A, yet it is possible for a cow to produce milk so poor in this vitamin that she cannot raise her own calf. Vitamin A is lacking in a mother's milk if her diet is continuously deficient in this vitamin. Lack of this vitamin in mother's milk would not be manifested at once if the diet had been previously adequate, since it is possible to draw for a time from that stored in the body.

Vitamin B

Vitamin B was the first to be discovered in connection with the study of the nerve disease beriberi. Vitamin B is often known as the antineuritic

vitamin. Lack of this vitamin not only retards or stops growth and leads to nerve disease, but causes other evidences of malnutrition as well. In man or other mammals the use of food unduly poor in vitamin B results in serious impairment of appetite, digestion, and general vigor, and inability to resist some types of infection before any nerve symptoms appear. Vitamin B is growth-promoting and as antineuritic it is essential to the health at all ages. It has very important functions in relation to appetite, digestion and general nutrition. Vitamin B stimulates the appetite and helps the body to become strong and resistant.

Vitamin B is widely distributed among natural food materials. On the whole it is easier to get a good supply of vitamin B than of some of the others, nevertheless it is just as important. In general it is only when the food supply consists too largely of artificial refined foods that there is danger of shortage of vitamin B. Because we have carried refinement of foods to such a high degree, and because this refinement is necessary to our present civilization, vitamin B will continue to be a factor in nutrition.

Like vitamin A, vitamin B is made by the living plant, and is also made by microörganisms such as yeast. Vitamin B is abundant in many of the common foods such as potatoes, and other root vegetables, fruits, cereal grains, such as whole wheat and corn; also peas and beans. It is especially abundant in yeast, in green leaves such as spinach, lettuce, leaves of turnips and beets. One of the best sources of vitamin B is the outer covering of wheat and

the wheat germ. Many people have found relief for nutritional disorders in eating whole wheat. There is no question of the value of this for some people, but at the same time, it must be remembered that if the nutritional disorder is not due to lack of vitamin B, eating whole wheat or any other whole grain will not necessarily be a remedy. Vitamin B is not found in fats either of animal or vegetable origin or in such manufactured products as starch, sugar and glucose. It is not found in adequate amounts in polished rice, degerminated corn meal, muscle meats, and sifted wheat flour. Although wheat flour should not be depended on as a source of vitamin B, yet since it constitutes on the average about one-third of the total diet, the amount of vitamin B furnished in this way is important even if not sufficient.

Vitamin C

Lack of vitamin C causes the disease known as scurvy, a disease that has been recognized since the twelfth century. Scurvy long ago became associated with a diet lacking in fresh food. That citrous fruits would prevent this disease was discovered in the middle of the eighteenth century. While lack of vitamin C may not produce the distinct symptoms of this disease, yet irritability, lack of stamina, retardation of growth, may be due to a diet poor in vitamin C. Low intake of this vitamin increases the susceptibility to infectious diseases but on the other hand the resisting power of the body may be increased by a sufficient amount of vitamin C in the diet. Vitamin C is not so widely distributed in dry

and cooked food materials as A or B, and for this reason this vitamin may be of greater economic importance. Vitamin C is made by living plants the same as vitamin A, but it does not necessarily require light for its production.

Raw fruits and fresh vegetables are ordinarily good sources of vitamin C. Among these may be mentioned tomatoes, fresh carrots, raw cabbage, lettuce, grapefruit, lemon juice, orange juice, raw young peas. Dr. E. V. McCollum reports that Jacques Cartier in 1526 saved many of his crew from death by having them drink, on the advice of Indians, an infusion of pine needles. The fresh needles of the pine, as well as leaves of many other trees, contain vitamin C. Raw milk contains some of this vitamin, but as it is very sensitive to heat, pasteurization destroys most of vitamin C. This practice is necessary to protect against epidemics of various kinds, and pasteurized milk should be used, but unless proper provision is made for a supply of vitamin C, pasteurization is costly to the infant population. Fresh, clear orange juice given to children will provide vitamin C. Clear juice from some vegetables would also be efficacious. Wheat flour, sugar, corn meal, potatoes, meat, oatmeal and peas are classed with the foods containing very little or no vitamin C.

Vitamin D

Vitamin D is known as the antirachitic vitamin; when present in the diet rickets will not develop; when absent it will develop, and when added to the diet of a child who has rickets it will disappear.

Physicians have found that when certain foods are fed, rickets never appear, and when these foods are fed to babies having the symptoms of rickets, these disappear. Analysis of bones of animals having rickets have shown them to contain only about 25 per cent mineral matter, while in normal bones the mineral matter is about 63 per cent. Cod-liver oil has long been known as a preventive and cure for rickets. When a few drops of cod-liver are fed for a while to experimental animals having rickets the bones become hard and strong. Cod-liver oil contains practically no mineral matter, hence its effect is not due to the addition of mineral matter to the diet, but to the fact that cod-liver oil contains some substance which enables the body to utilize the mineral matter which is furnished. Rickets is not due ordinarily to lack of mineral matter in the food, but to the failure of the body to utilize what is furnished. Hence in the absence of vitamin D it will avail little to add mineral substance to the diet.

Vitamin D is made by the action of ultra-violet light on certain chemical compounds. These need not necessarily be present in the living plant, which means that this vitamin can be produced without the agency of the plant. Butter, egg yolk and some fresh green vegetables are the only common foods which have been shown to contain vitamin D in appreciable amounts. These foods, however, appear to be less effective than cod-liver oil. There is more in egg yolk than in butter. Liver oils of fishes generally are good sources of vitamin D. Other food-

stuffs, except those mentioned, are deficient in vitamin D. This means that people in general, and especially children, get an insufficient amount of this vitamin unless provision is made to supply the need, as will be described in the next paragraph.

While vitamin D is scarce in ordinary food material, there is at hand an unlimited source of energy which can prevent rickets and even impart the same properties to certain foods as are associated with vitamin D. This is sunlight, free and uninterrupted, or any source of light which furnishes ultra-violet rays. Experimental animals placed in the dark develop rickets much more rapidly than those kept in the light. Black rats develop rickets much more rapidly than white rats. It has recently been found that when certain foods which ordinarily produce rickets in rats are subjected to the influence of direct sunlight or the light of the quartz mercury vapor lamp, they will not produce rickets. Olive oil in its natural state does not possess curative properties against rickets, but when subjected to the action of the light of this lamp it becomes almost as good as cod-liver oil. That this discovery of producing antirachitic properties in food by the action of ultra-violet light may be prevented from exploitation it has been patented by its discoverer, Dr. Henry Steenbock, and by him generously donated to the University of Wisconsin. It is reported that Dr. Steenbock was offered over a million dollars for this discovery.

Rickets is said to be very rare in the tropics. This can be ascribed to the constant irradiation of the

skin with the intense rays of the sun. Rickets is not prevalent in the Arctic regions where the food is composed largely of fish or of animals which feed upon fish. Rickets is most prevalent in the north temperate zone. It is more prevalent where people live in poorly lighted quarters than where they are more out in the open sunshine. It is ultra-violet rays of sunlight which are effective, and these are filtered out by ordinary window glass.

Vitamin E

Students of nutrition have found that it is possible to grow some experimental animals to maturity on certain diets in an apparently normal manner, but they are sterile. These animals are sleek and healthy looking. A study of the female shows that the ovarian function is normal at first, but they are unable to complete their pregnancy and produce normal young. Inclusion in the diet of whole wheat, wheat germ, or the addition of lettuce or muscle meat restores the fertility. Muscle meat is more valuable for this than liver tissue. In regard to the importance of vitamin E in human nutrition Dr. E. V. McCollum has this to say: "So far as is known it seems improbable that the deficiency of vitamin E has any importance in determining sterility in humans because of the distribution of the vitamin in natural foods is such that people are not likely to run short of it. It is possible, however, that sterility in domestic animals may in some cases be due to the deficiency of this vitamin, but no case is yet demonstrated to be due to this cause. Other errors in feeding may have a profound effect on fertility."

The General Supply of Vitamins

The best place to secure vitamins is in the natural foods obtained from the farm, garden, or the grocery store; and not the drug store. There is little reason why people should suffer for the want of any of the vitamins if they understand where they may be easily obtained. Some work has been done on producing vitamins in the laboratory. This is of more scientific than practical interest at the present time. Some eminent authorities do not think that isolation of the vitamins in a pure state or the discovery of a method of manufacture would be of any practical importance. Below is given a list of foods and their relative content of vitamins A, B, and C. Similar tables have from time to time been published by students of nutrition. Vitamin D is not included because there is only one important source, cod-liver oil, and this has been mentioned. Other sources of vitamin D are fish foods, egg yolk, some fresh vegetables, and butter from cows on an adequate diet. Besides, treatment of certain foods with ultra-violet light imparts the properties possessed by vitamin D. Very little is known of vitamin E and its importance in human nutrition seems to be very small. Only those foods rated "good" or "rich" should be depended upon as adequate sources of vitamins. Those rated "fair" or "poor" may be important sources if other foods rated good or rich are used as well. Since it is practically impossible to prove the absolute absence of any vitamin, the foods considered as lacking in any of the vitamins are rated as containing a trace or poor in vitamin content.

RELATIVE VITAMIN VALUES OF SOME COMMON FOODS

	A	B	C
Apples, raw	poor	poor to good	good
Bananas, raw	poor to good	poor to good	good
Beans, navy	poor	rich	?
Beans, string, cooked	good	good	?
Beets, leaves	good	good	?
Bread, white (water)	?	poor	trace
Bread, white (milk)	fair	poor	trace to poor
Bread, whole wheat, water	poor	good	?
Bread, whole wheat, milk	good	good	trace to poor
Butter	rich	trace	trace
Buttermlik	poor	good	poor or variable
Cabbage, head, cooked	poor	good	poor
Cabbage, head, raw	poor	good	rich
Cabbage, green, raw	good	good	rich
Carrots, fresh, young	rich	good	good
Carrots, old, raw	rich	good	poor
Chard	good	poor to good	?
Cheese, whole milk	good to rich	?	?
Coconut oil	trace	trace	trace
Cod-liver oil	rich	trace	trace
Corn, white	poor	good	trace
Corn, yellow	good	good	trace
Cottage cheese	poor	?	?
Eggs	rich	poor to good	?
Lard	little	trace	trace
Lettuce	poor to good	good	rich
Liver	good to rich	good	poor
Meat, muscle	trace	trace	trace
Milk, whole	rich	good	poor to variable
Milk, condensed	rich	good	poor to variable
Milk, fresh skim	poor	good	poor to variable
Oatmeal	poor	good	trace
Onions, cooked	trace to poor	poor	poor
Orange juice	poor	good	rich
Peanuts	poor	good	?
Peas, canned	good	good	good

RELATIVE VITAMIN VALUES OF SOME COMMON FOODS—(*Continued*)

	A	B	C
Potatoes, sweet	good	good	good
Potatoes, white, boiled.....	poor	good	poor
Potatoes, white, baked	poor	good	poor
Prunes	good	good	trace
Raisins	trace	poor	trace
Rice, polished	trace	trace	trace
Rice, whole, grain...	poor	good	trace
Sauerkraut.....	poor	poor	trace
Spinach, cooked ...	rich	rich	poor
Tomatoes, raw or canned	good	good	rich
Yeast	trace	rich	trace

Stability of Vitamins

It is very important to know something about the stability of vitamins. A food may under natural conditions be a good source of a certain vitamin, but the methods of preparation of a food may be such as to destroy it. Vitamin A is destroyed by oxidation, hence prolonged heating in contact with air destroys it. However, in ordinary cooking the extent of its destruction is not so great. Vitamin B appears to be the most stable. Ordinary cooking, not even the prolonged heating necessary in canning, seems to destroy vitamin B in a degree which is of any practical importance. Vitamin C is the most unstable of all the vitamins. It is destroyed when milk is pasteurized, especially if it comes in contact with the air. Vitamin C should therefore be provided in those foods which can be eaten raw, such as citrous fruits, tomatoes, cabbage and lettuce. Destruction of vitamin C takes place more by oxida-

tion than by heating. Research work by the National Canners Association has shown that foods may be canned and at the same time preserve vitamin C. If the materials to be canned are first immersed in slightly salt water for a few hours, the oxygen is used up by the cells of the tissues and then, when the material is boiled, there is no oxygen to destroy vitamin C. As this practice is not general, canned goods should not be considered adequate sources of vitamin C. Acid seems to be a preserver of this vitamin, hence such acid fruits as the citrous and tomatoes are good sources. The stability of vitamin D appears to be similar to that of A.

This survey of the vitamins shows that wheat flour should not be considered a source of vitamins. When good butter is eaten with bread, vitamin A is provided, unless in exceptional cases when the cows have been fed on a very inadequate ration, but as has been shown there are a number of other good sources besides butter. Vitamin B is the only one which appears to occur in any abundance in wheat, and most of this is in the outer bran coat and the germ. While there are exceptional situations, such as famine, in which it may be necessary to use this as a source of vitamin B, and while many people have been benefited by eating whole wheat, yet the general supply of this vitamin in common food substances is greater than that of the other vitamins and there should therefore be no reason for lack of this vitamin in the ordinary diet. Vitamins C and D must be provided in foods other than that from wheat. Wheat bran and wheat germ are important sources of vitamin E, but the importance of this vitamin for humans is very small.

CHAPTER XV

THE RATIONAL PLACE OF WHEAT FLOUR IN THE DIET

WHENEVER there is an oversupply of any commodity it is natural to start a campaign for increased consumption. At the present time statements like the following are often made: "Eat more bread," "Bread is the best and cheapest food." A little thought would show that any campaign conducted for increasing the consumption of wheat or any other food will not be very effective unless it is based upon sound reasons. People are guided by two main considerations in the selection of food: namely, appetite, and instruction in what is best for their health. Economy with many people in the United States seems to be secondary. Before we had our modern dietary standards and our modern health books and health teachings, appetite was the main guide and where it was not perverted it was the best available. Now since there is available so much instruction in what is best, health education will largely influence our considerations in selecting food. The propaganda which has for its slogan "Eat more bread" will land nowhere, since there are other propaganda which have for their slogan such as these: "Drink more milk" and "Eat more meat." It is simply

impossible to follow such advice and it is well to remember that eating too much may be as harmful as eating too little.

Cereals have been used as a principal part of the diet since time immemorial and the practice will be continued. Economically they are of primary importance, since they furnish more food for the same amount of money than any other staple article, but sound education in regard to the use of these cereals is necessary. It must be understood that wheat flour is deficient, at the same time it is necessary to show in what way the deficiency should be remedied. It has been shown by students of nutrition that an adequate consumption of dairy products together with some meat will help the deficiency and also that more leaves of vegetables as well as uncooked fruits and vegetables are necessary. In certain countries where rice is the main staple article of diet, people learned long ago that the leaves of vegetables and uncooked vegetables furnish protection against certain diseases, showing that a successful diet may consist practically wholly of vegetable food. On the other hand the diet may consist almost wholly of animal food as shown by the fact that some of the most sturdy people in the world are those who live on the great plains of Asia and get most of their foods from animals in the form of milk and meat. When cows are fed under natural conditions the composition of milk is such that it will correct in a very effective manner the dietary deficiency of wheat flour, and according to some of the best authorities on nutrition the simplest, cheapest and most effective way to improve the quality of

bread is to introduce more milk solids into its composition.

The very civilization which has given us many comforts of life, has brought at the same time a number of nutritional problems. Man has lived for a long time on this earth, but formerly life was much simpler than it is now and more people lived directly from the soil. When each family had their own vegetables, cow, and hens, the problem of an adequate diet was more simple. Moreover, the cows had green pastures in the summer and in the winter they were fed on feed produced from whole plants. The largeness of modern cities has made the nutritional problems more difficult since vast numbers of people must receive their food from a long distance. This means that a large portion of the food must stand transportation and storage for considerable periods. Under conditions of modern civilization, what place should wheat flour occupy in a rational scheme of nutrition? What proportion of the total nutrients comes from wheat flour and what must be furnished as proper supplements?

It has been shown in connection with dietary standards (Chapter XI) that for an average man the daily diet should contain about 100 grams of protein and enough fats and carbohydrates to furnish 3,000 Calories, and that for women because of difference in body weight the Calorie requirement is four-fifths as large as for men, and that for children of different ages the requirement in round numbers is from three-tenths to four-fifths as much as for men. It was also shown that the average protein requirement of women is 90 grams per day and of

children from 28 to 75 grams per day, and also that the Calories required as an average for all the people is about 2,000 per day.

Since one gram of protein supplies 4 net Calories, and one gram of carbohydrate the same, we can figure that in a diet which supplies 3,000 Calories per day, four hundred Calories come from the 100 grams of protein and that 2,600 Calories are supplied by the fats and carbohydrates. One gram of fat gives nine Calories. The relative proportion of fat and carbohydrates need not be fixed; it is only necessary that enough of each be supplied to provide the total calorific requirement. It is simpler, therefore, to calculate the equivalent in carbohydrate and to supply the 2,600 Calories would require 650 grams. On the basis of 100 grams protein per day and enough fuel foods in addition to supply a total of 3,000 Calories per day, an average working man would need per year 80 pounds of protein and 520 pounds of carbohydrates. These six hundred pounds figured as pure substance would provide 1,087,000 Calories. If we multiply 3,000 Calories per day by the 365 days of the year we get 1,095,000 Calories for a man, which is close enough agreement to the above figure for calculations of this kind.

In Chapter II it was shown that the best recent estimates place the amount of flour consumed per capita in the United States at 180 pounds per year. On the basis of this figure and the estimate of 2,000 Calories per day as the average for all people we found that flour supplies nearly 40 per cent of the total calorific requirements. There is some waste in all food materials, but there is probably less in bread

than in any other staple food, unless it is sugar, but the facts seem to be that as an average estimate wheat flour furnishes about 40 per cent of the total calorific requirement of the people of the United States. With people who have to practice rigid economy with food, this amount will be larger. With people who are able to be more liberal with their food expenditures this amount will be less.

On the basis of the figures for composition given in Chapter II, 180 pounds of flour analyzing 11 per cent protein, and 73.60 per cent carbohydrate, would contain 19.8 pounds of protein and 132 pounds of carbohydrate. This is the average furnished by wheat flour to each man, woman and child. When the daily protein requirement is placed at 100 grams and the total calorific requirement 3,000, then the amount of protein equals 80 pounds per year, but the average calorific requirement for all the people is 2,000 per day or two-thirds of the above amount. On the basis of the same ratio for the protein requirement the annual amount would be 53⅓ pounds per capita. It is necessary to assume a more liberal protein supply since the children are included in this average. If we assume a protein supply proportionate to 2,400 Calories, the annual protein requirement would be four-fifths of 80 or 64 pounds. This would be at the rate of 80 grams per person per day and this is considered a liberal protein supply. The 19.8 pounds of protein furnished by the 180 pounds of wheat flour would then be a little over 30 per cent of the total annual protein requirement figured for all the people. It is true that protein from wheat flour is not a balanced protein,

but it will be shown in what follows that other foods which balance this protein are supplied in liberal amounts.

The need of the body for certain mineral elements was discussed in Chapter XII and it was shown that one of the greatest deficiencies of wheat flour is lack of mineral matter. The human body needs at least ten mineral elements, and all seeds are as a rule deficient in six of these elements: namely, calcium, phosphorus, iron, iodine, sodium, and chlorine. The last two are supplied in common salt and need not concern us here. Lack of iodine in the diet causes goiter. This lack may be supplied by iodized salt, by water treated with iodine under competent supervision, or by some foods which supply iodine. The actual amount of iodine needed is very small, only (three thousandths) 3-1000 of one gram per week, and it is easy to do harm with an over dosage. Good sources of iron are meat, eggs, raisins, bran, dried peas, beans, spinach. These are also foods which are good sources of vitamins. The elements calcium and phosphorus are needed in large amounts by the body and these elements are not found in sufficient amounts in flour.

Probably one of the most frequent suggestions made for supplying the mineral deficiency in flour is that the use of white flour should be restricted and that all of the wheat should be included in the diet. Could the need for calcium and phosphorus be supplied in this way? Whole wheat contains 0.05 per cent of calcium and 0.37 per cent phosphorus. Flour contains .02 per cent calcium and .09 per cent phos-

phorus. The minimum average phosphorus requirements per day has been placed at about one gram and that of calcium 0.7 grams. One pound of wheat contains .225 gram of calcium and 1.67 gram of phosphorus. One pound of flour contains .09 gram of calcium and 0.40 gram phosphorus. The 180 pounds of flour per capita consumption means very nearly one-half pound of flour per day. If this amount was consumed as whole wheat people would get 0.112 gram of calcium and 0.83 gram of phosphorus, which is much less than the minimum. To supply the total phosphorus requirement would take 0.6 pounds of whole wheat and hence it might be possible to get all the phosphorus from this source by increased wheat consumption. The calcium requirement could not be supplied by eating whole wheat. To get enough calcium would require the daily consumption of over three pounds of whole wheat flour having a total calorific value of 4,925, and the consumption of such an amount of any one cereal is simply impossible. It is still more impossible with flour, and hence it is necessary to look to other foods for the calcium supply. Some of these foods which supply the needed calcium are also good sources of several other mineral elements as well as the vitamins.

Milk, certain green leafy vegetables, roots, nuts, are all rich in calcium. Other foods which supply liberal amounts of calcium were mentioned in Chapter X. Milk is the best supplement to wheat bread, and there is an abundance of milk produced in the United States. Some students of nutrition advocate

that the daily diet of the average adult person should include a quart of milk. According to figures compiled by the Bureau of Agricultural Economics, United States Department of Agriculture, the amount of milk produced annually amounts to 118 gallons for each person. This would supply considerably more than a quart a day for each person. About half the milk is manufactured into dairy products and the rest sold as market milk, averaging about 1.2 pints per person per day. The arguments for manufacturing milk into dairy products such as butter and cheese are very similar to those for milling wheat. They are greater keeping quality, easier distribution at less cost, and increased variety of palatable foods.

The per cent of calcium in milk is .12 or, weight for weight, 6 times as much as is present in flour and 2½ times as much as in whole wheat. One quart of milk contains 0.84 gram of calcium or somewhat more than the daily requirement of the average person. People do not need to get all the calcium from milk. If in addition to milk a fair amount of vegetables besides potatoes are eaten the calcium requirement, as well as the need for the other essential minerals, will be met. From the amount of milk and vegetables consumed in the United States it would seem that the people as a whole do not lack for calcium, but as was pointed out in connection with vitamins, it may not be lack of calcium in the diet which causes trouble, but the non-utilization of the calcium which is furnished. Such non-utilization is due to lack of vitamin D or to living too much in the absence of ultra-violet light.

A Most Common but Deficient Diet

Probably the diet which is most deficient on the American table is the so-called bread, meat, and potato diet. The meat proteins are good in balancing the porteins of wheat bread, but meat does not balance bread in other respects. Meat by itself is not a balanced ration any more than white bread. It supplies no carbohydrate, it is low in calcium, is not a good source of vitamins, and it has no indigestible residue. Potatoes contain 18-20 per cent starch, 2-2½ per cent protein, one per cent ash and 75-79 per cent water. The per cent of calcium is .011 or about half that of wheat flour, and the per cent of phosphorus is .07, a little less than wheat flour. Hence potatoes are more deficient in the same elements in which flour is deficient and cannot balance this food. Bread, meat, and potatoes are good foods, but they need to be balanced with milk and particularly those vegetables which furnish the needed mineral elements as well as the vitamins.

From what has been said it follows that the place of wheat flour in the diet is to supply about two-fifths of the total calories and a little more than 30 per cent of the total protein. The mineral deficiency of wheat flour must be made good by the inclusion of milk and certain vegetables in the diet. The wheat proteins are best balanced by those from milk, eggs and meat. The foods which balance wheat flour in respect to mineral elements and protein also supply several of the vitamins.

CHAPTER XVI

WHEAT FLOUR IN RELATION TO HEALTH

Probably no other single article of food has been subjected to so much misrepresentation as wheat flour. How much this has had to do with the decreased use of flour in recent years it is impossible to say, but it has no doubt had an influence with some people. Sometimes teaching against wheat flour is actually pernicious, besides it is false and unfair. White flour has been blamed for nearly every kind of human ill. White flour has been said to cause cancer, appendicitis, stiff muscles, poor teeth, and so on. The lack of mineral matter in flour is often cited. Flour does lack mineral matter, but the facts are given such setting that a wrong impression is given. Many other perfectly good foods such as sugar, potatoes, and meat are also lacking in mineral matter. Since wheat flour constitutes on the average one-third of the total food and is thus a larger source of food in the daily diet than any other single item, it is easy to blame wheat flour.

Good health depends on a number of conditions of which food is only one, although one of the most important. It is not contended that correct eating alone will necessarily keep a person in good health but it will help probably more than any other thing under a person's control. The following paragraphs

aim to show some of the intimate relationship between food and health.

Good health is a fortune sometimes little valued by people who have "abundant health." Circumstances surrounding their birth gave them a good fund of vitality to start with, and subsequent environment has continued to guard them against those conditions which destroy health. Such people are likely to take their health, like sunshine, for granted, and they may have little interest in the relation of food to health. However, experience shows that many such persons of stalwart physique and apparently in abundant health are stricken down in middle life, while others seemingly less strong but more solicitous for health preservation continue to live and work efficiently to mature years.

Good health should not be taken for granted. A person with abundant health may think that his vitality is unlimited. He eats what he likes and partakes of those pleasures which come his way without thought of consequences. But vitality is not unlimited. While nature is very kind, and willing to repair damage time and again, there is always a limit. When this limit has been exceeded, the person may awake to the importance of obeying the laws of health. If the damage has not been too great health may be restored, but the chances are that the same abundant life enjoyed before will not come back. That the right kind, variety, and amount of food has a very important bearing on health preservation needs to be recognized by every one.

Poor health is expensive, and it is much better

both economically and otherwise to preserve health than to restore health after it has failed, particularly if this can be done by right habits of eating. The annual sick bill of the people of the United States amounts to billions of dollars. In this bill should be listed not only what people spend for doctors' bills, hospital bills, medicine, but also decreased efficiency due to lack of good health. The annual drug bill of this country is given in round numbers as $500,000,000, of which $300,000,000 is spent for patent medicines. While many drugs have curative values in the hands of skilled physicians, it may be said that most of this money is worse than wasted by the people who try to recover health. The number of drugs is increasing at an enormous rate. Thirty years ago, 2,699 drug items were listed on the market. To-day more than 45,000 are reported by reliable authorities to be in use. While many of these are of great value, some do an immense amount of damage because of ill-advised or indiscriminate use. More attention to diet and less attention to drugs would save much of this money spent in health recovery.

One of the reasons for better health preservation in recent years is the added emphasis placed on the importance of diet. People eat to live, but what they eat and how they eat has much to do with health. Health may be destroyed by some disease, but the coming of this disease may be traced to a faulty diet. The direct cause of the disease may be germs which live and grow in the body, but the reason they can live and grow there is lack of resistance, and this may be due to a faulty diet.

The mechanism of the human body is very complex. It may be likened to a chemical factory in which the most wonderful chemical and physical changes take place. In this factory proteins, fats, carbohydrates and mineral matter present in the food are transformed and used to build, repair and give energy to the body. The body may also be likened to an internal combustion engine, only infinitely more complex and more delicate. All have an admiration for a strong, powerful, smooth-running engine. It signifies power. It means ability to do work. But no man-made machine has power of self-direction and self-repair. This function belongs to beings which have life, and food furnishes the material to keep the body in working order.

Life is dependent on certain proper and fine adjustments of time relations. In an internal combustion engine the rate of gas flow, the rate of combustion, the related movements of piston valves are all necessary for the smooth running of the engine. In a similar way there are several interdependent time relations of the body, such as rate of heartbeat, rate of respiration, rate of metabolism, or the rate at which food is consumed in the blood and tissues, the rate of digestion, the rate of elimination by the kidneys, skin, and lungs. All these time relations are of vital importance to the smooth, healthy working of the body as a whole and hence the importance of the proper amount and kind of food.

For the successful running of an internal combustion engine it is not only necessary to have gas for fuel, but also oil to prevent friction, and a cooling system to maintain proper temperature. Then the

machine parts wear out and must be repaired. Similarly in the body certain foods are used mainly for fuel, others have distinctive repair functions, while certain foods are classed as protective foods. The body has a mechanism for maintaining a proper temperature. Every complex machine, from the power engine to the loom, from the printing press to the watch, is equipped with numberless automatically working devices of fine control and self-adjustment. In a good watch this self-adjustment to temperature changes is such that it will not vary a second between summer and winter temperatures. In the same way the body has self-adjustments or self-regulators. When given the proper chance, these take care of external changes to which the body is subjected. But the mechanism is delicate and should be given at least as good treatment as is given to an engine or other complex mechanism. These perform their functions properly and give good service as long as they receive fair treatment. In the same way the body will remain in good health, will be able to perform work, and give joy to its possessor if he will live according to the laws of his being. In no sphere can man as easily influence his health as in the selection of the food he eats.

There are two main causes of disease. Disease germs invade the body and cause damage in most cases through the production of poisons known as toxins. These poisons act either on the respiratory nerve centers or on some other vital organ, or they gradually poison the whole body. Examples of such diseases are diphtheria, typhoid, smallpox, as well as some other contagious and infectious diseases.

Not all people who get a disease due to invading germs die. It was discovered long ago that while in some epidemics many people died, many got well. This means that the body may conquer in the struggle. With some diseases, such as smallpox and typhoid, the body stores enough antibodies so that these disease germs are not likely to invade the body again. Against such diseases whose nature is well enough known it is possible to immunize the body by vaccination. The chances of a person winning in the struggle against a germ disease depends on his store of health and vigor or resistance. Food and living habits have a great deal to do with giving people their resistance or immunity.

The other main cause of disease is in the failure or some irregularity in the complicated chemical and physical reactions which continually take place in the body. When these reactions are normal from day to day the body is in good health. Abnormalities or irregularities in the reactions are a direct cause of such diseases as gout, diabetes, goiter, as well as various kinds of stomach and digestive troubles. If the stomach does not do its work properly the person is not well and this may be the beginning of other diseases. The heart may be weak and this in turn will be the cause of a whole train of trouble. The liver or the kidneys may not function properly, and this is the direct cause of sickness. Any disease due to the failure of an organ to do its work is called a functional disease. It means that some part of the body machinery is out of order. When these conditions occur, the natural resistance of the body against disease germs is lowered. The

failure of any organ in the body to function properly may be an indirect cause of sickness and death from disease germs. Thus a person may die from lung trouble as a direct cause, but the cause of the lung trouble may be lessened resistance due to faulty living and eating.

The right kind of food in proper amounts is of the utmost importance in maintaining health. Some people overeat and thus cause overtaxation of some organs of the body. Some people undereat and so deprive the body of some of the material needed for different functions. Here lies the danger of the indiscriminate reducing diets. An engine may be choked by a too rich mixture, but the mixture may also be so lean that it stalls when a little extra exertion is required. Sometimes the food may be proper as to amount but it may lack certain substances needed for the proper functioning of the body. If this is the case, the body gets out of repair. It means that it wears out faster than normal, it means lack of energy to do work. Old age comes on faster than it should. Age from the standpoint of physiology is not measures so much by years as by physical fitness and abundance of life. Some people are old at 50, others are young at 70. The hardening of the arteries, the common enemy of man after he has passed middle life, is very strongly suspected of being related to nutritional factors. In other words, it is related to right kinds of foods. The resultant diseases of high blood pressure, such as kidney and heart troubles, are thus related to an improper diet.

The human body starts from a very small microscopic cell. By small increments from day to day it

develops first into the tiny babe, and in a series of years this babe grows into a strong man or woman. During all this time the food must furnish not only an abundance of material, but the material must be of the kind needed to build a strong body. Very often the foundations for weakness in later life are laid during infancy and childhood because the food lacks the proper materials to build a strong body.

After maturity has been reached the body, like all machines, must be kept going. Parts wear out and must be repaired. The body has the power of self-repair and all that is needed to do is to give it the right materials and the proper chance. The body is made of bones, muscles, fats, various tissues and fluids. The food must furnish the material for building these substances in the body, repair worn-out parts as well as furnish material for fuel. The body also needs air and water; the air to furnish oxygen for combustion, which is the source of energy, and the water as the principal medium of transportation. No one food is sufficient when any one serves as the sole source of nutrition. This holds for animal foods, some more than others, but more so for the cereals. It is true that some foods such as milk and eggs provide nourishment for the young during a certain period but we are considering the dietary requirements as they are for all the people. In the process of evolution the human body has had access to various kinds of food and hence it seems to require a variety. It therefore seems proper to say that practically all our natural foods are incomplete if we were limited to any one food. If cereals are incom-

plete when used as whole grains they are still more incomplete after they are milled. The most incomplete milled products are bolted wheat flour, degerminated corn meal and polished rice. Feeding experiments have established that the remedy for this deficiency is not in the use of whole grains, and hence the advocates of their use do not give us the true solution. It has been shown in experimenting with animals that wheat alone produces no growth and gives a short life, but it has also been shown that wheat plus an adequate amount of protein, whether from animal or vegetable sources, plus mineral salts, plus vitamins, produces good growth, good maintenance, normal number of offspring, good rearing of the same, and normal life span.

Bolted wheat flour is of value as a source of protein and carbohydrates. Its protein is not as complete as the protein from milk and some other animal foods, but it has a value as protein when fed in connection with the proteins from milk, eggs, and meat. The inorganic content of wheat flour is wholly inadequate. It is particularly lacking in calcium or lime, phosphorus, sodium, and chlorine. The grinding of the whole wheat into a meal and using it as a food will not help this deficiency. It is true whole wheat contains more of the mineral elements than white flour, but the elements mentioned are still insufficient. One of the mineral deficiencies in wheat is the unbalanced ratio of calcium to phosphorus. Four-fifths of the phosphorus of the wheat berry goes into the bran and shorts. If this phosphorus is included in the diet by using whole wheat the unbalanced ratio between calcium and phos-

phorus still exists. Whole wheat contains more vitamins than bolted wheat flour, particularly vitamin B, but this vitamin is one of the vitamins least likely to be lacking in the diet. One of the most important vitamins removed from wheat flour in bolting goes with the germ to the shorts. Our present civilization demands wheat flour that can be stored for a considerable length of time. The germ is very rich in fat and if the germ is left in the flour it could not be stored without becoming rancid, and the necessity for flour storage is as ancient as civilization.

Lately there has been much work done in trying to make bread an absolutely complete food. In fact, bread has been made which is so complete that several generations of healthy white rats have been produced when they have had nothing to eat but this bread. It is necessary to remember, however, that the dietary requirements of humans are not exactly the same as that of white rats, since they are immune to scurvy, although all agree that these rats have been of tremendous and incalculable service in the study of human nutrition. Making wheat bread a more complete food is good, but we must not think that this is an essential thing to do, and it may not even be for the best, since mineral elements, the protein needed to balance wheat protein and vitamins may be obtained more satisfactorily in other foods.

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